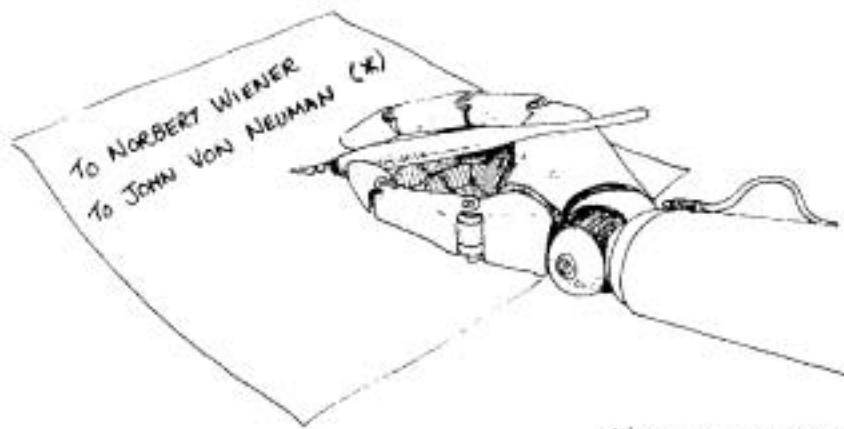


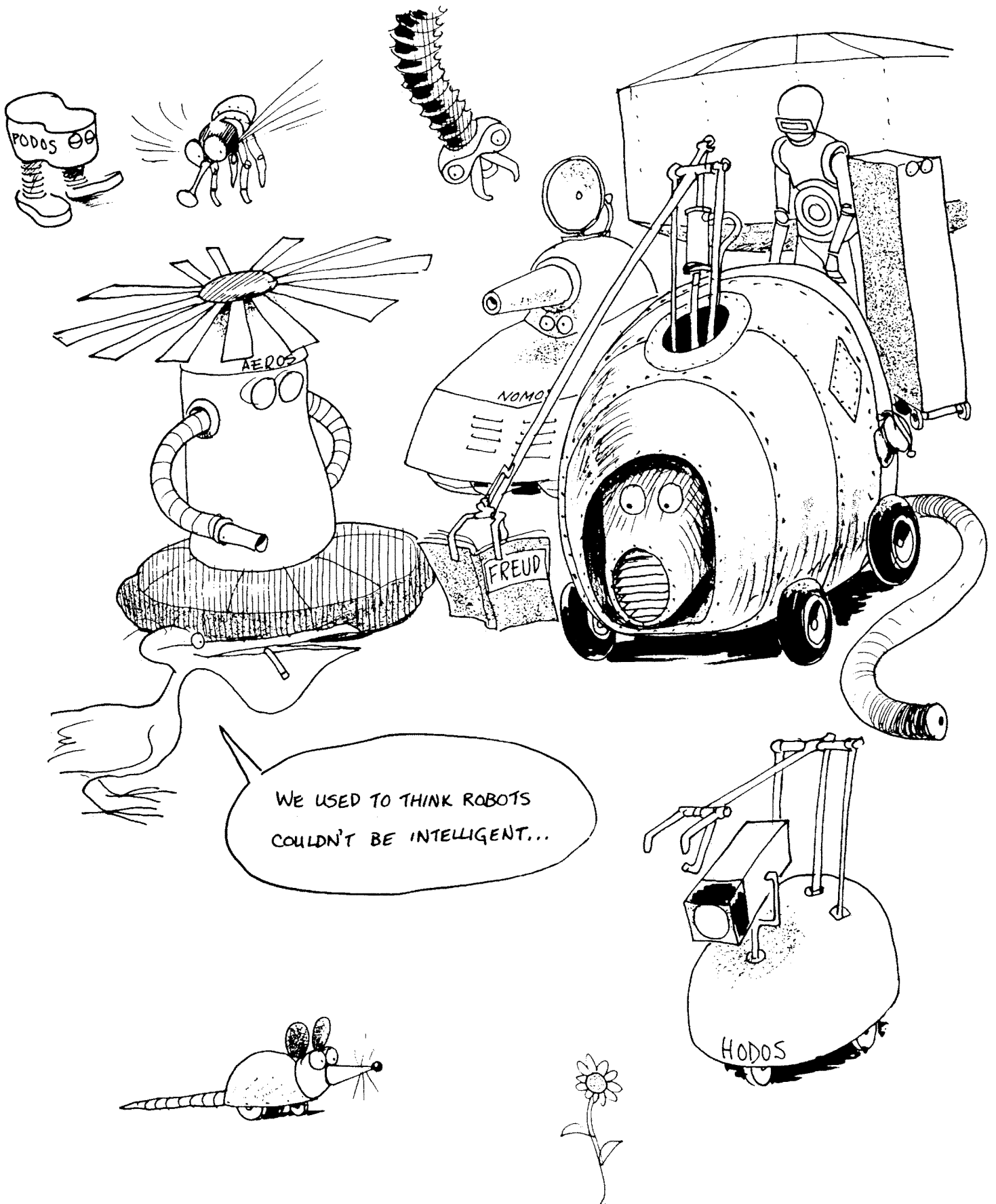
**The Adventures of
ARCHIBALD HIGGINS**

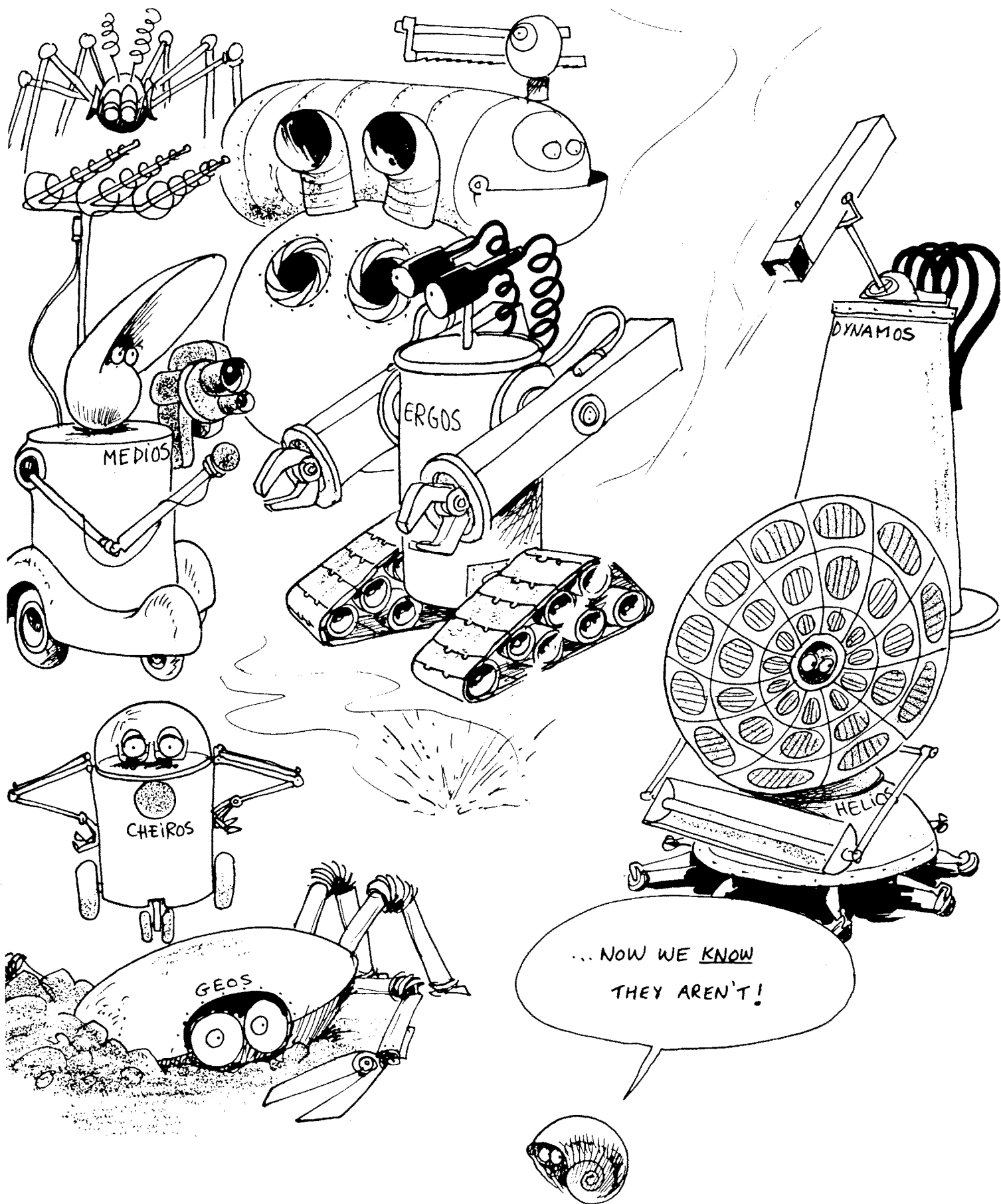
RUN, ROBOT, RUN

Jean-Pierre Petit



(X) AND OTHER CYBERNETICISTS





The Association Knowledge without Borders, founded and chaired by Professor Jean-Pierre Petit, astrophysicist, aims at spreading scientific and technical knowledge in as many countries as possible and in as many languages as possible. To this end, all his popular scientific works, which cover a period of thirty years, and more particularly the illustrated albums he has created, are now freely accessible. Anyone is now free to duplicate the present file, either in digital form or in the form of printed copies and circulate these copies to libraries, within the context of schools or universities or associations whose aims would be the same as the association, provided that they do not derive any profit from this circulation and that they do not have any political, sectarian or confessional connotations. These pdf files may also be put on line in the computer networks of school and university libraries.



Jean-Pierre Petit intends to create numerous other works which will be accessible to a larger audience. Even illiterate people will be able to read them because the written parts will “speak” when the readers click on them. Thus it will be possible to use these works to support literacy schemes. Other albums will be “bilingual” in so far as it will be possible to switch from one language to another selected language with a mere click. Hence another tool made available to develop language skills.

Jean-Pierre Petit was born in 1937. He made his career in French research. He worked as a plasma physicist, he directed a computer science centre, he has created softwares, he has published hundreds of articles in scientific magazines, dealing with subjects ranging from fluid mechanics to theoretical cosmology. He has published about thirty books which have been translated in numerous languages.

The association can be contacted on the following internet site:

<http://savoir-sans-frontieres.com>

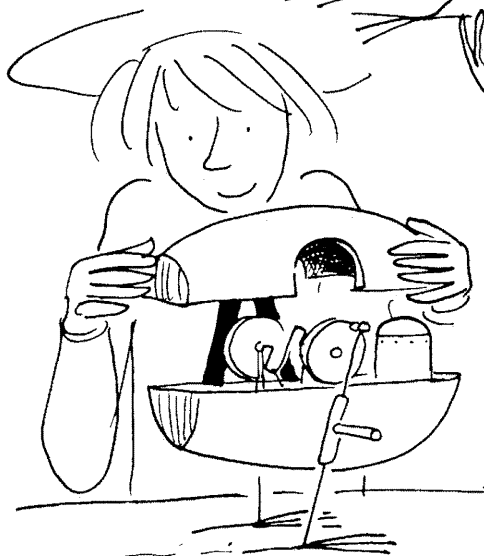
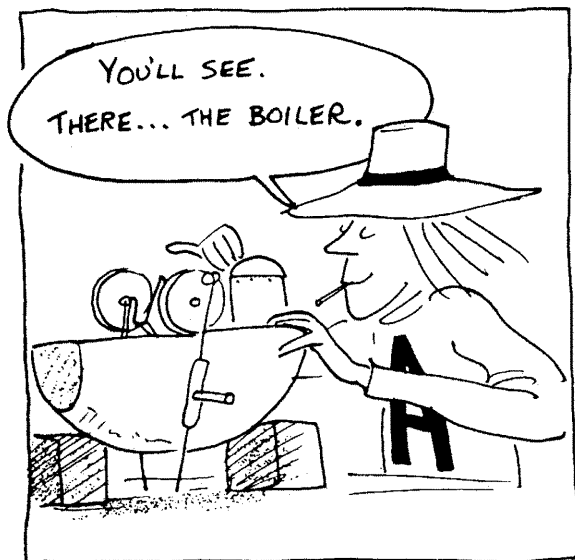
PROLOGUE



H'ARCHIE —
WOT YER MAKIN'?



A BOAT?



THAT'S NO BOAT.



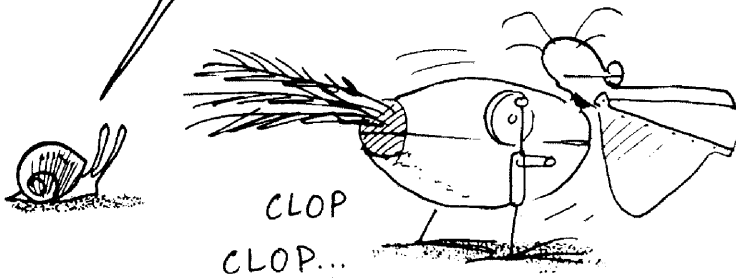
HUNH?



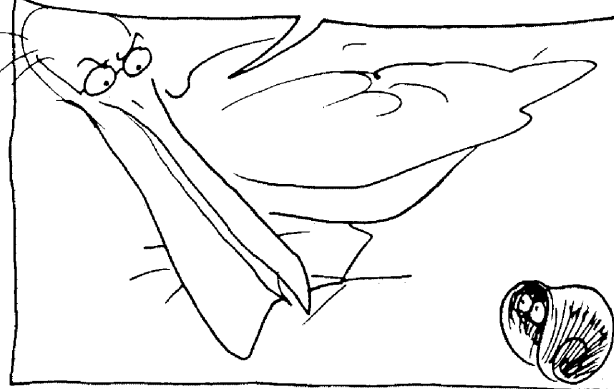
OH, WOW!
A STEAM-PELCAN!



LOOKIT, LOOKIT!
IT WALKS!



OH, STUFF IT, TIRESIAS!
ONE O' THESE DAYS YER'LL
BE LAUGHIN' ON THE UVER
SIDE O' YER BLINKIN' FACE!

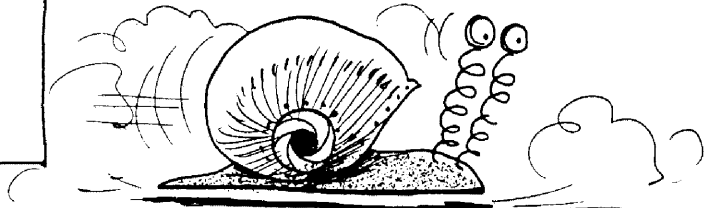


SEE WOT
I MEAN?

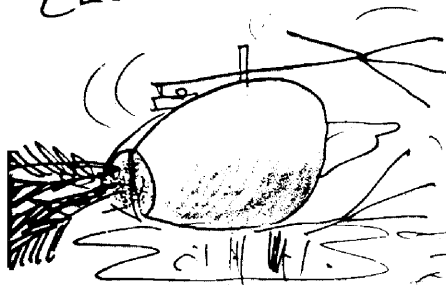


A HOVERSNAIL ON
AN AIR-CUSHION!

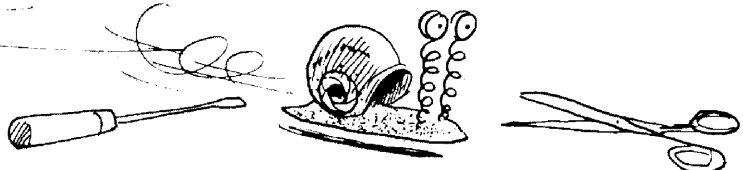
WHOOOARRR

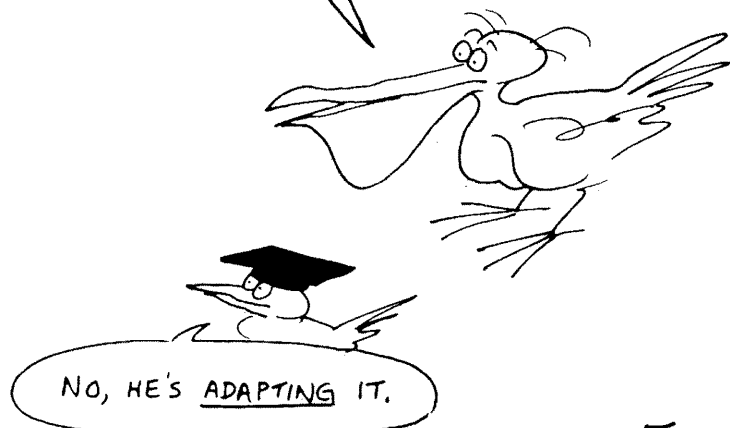
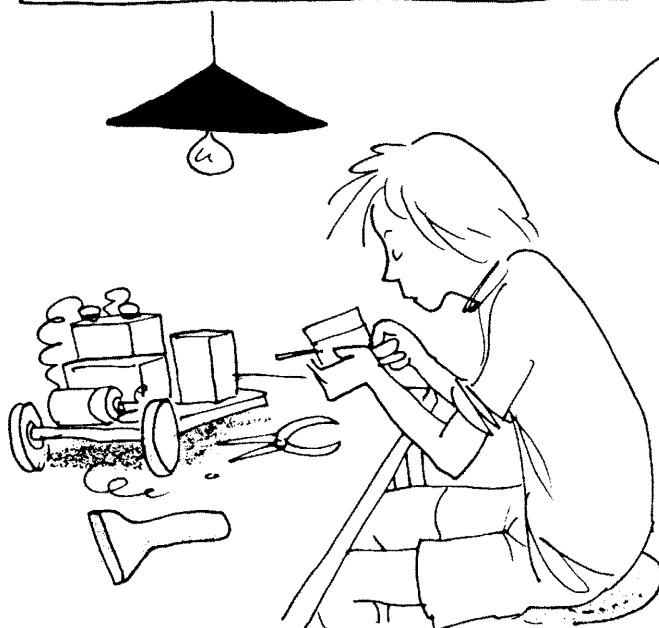
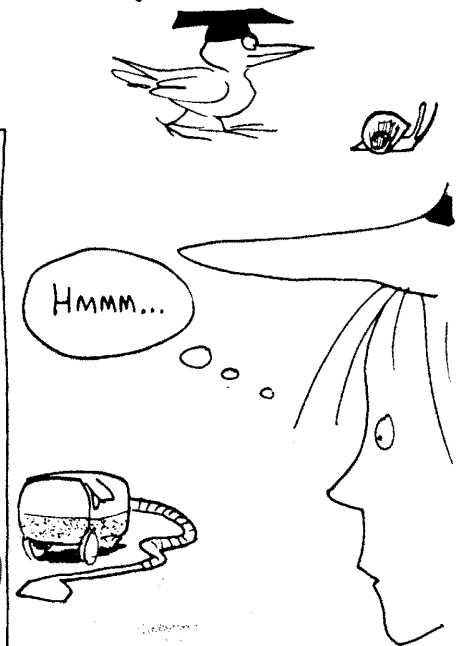
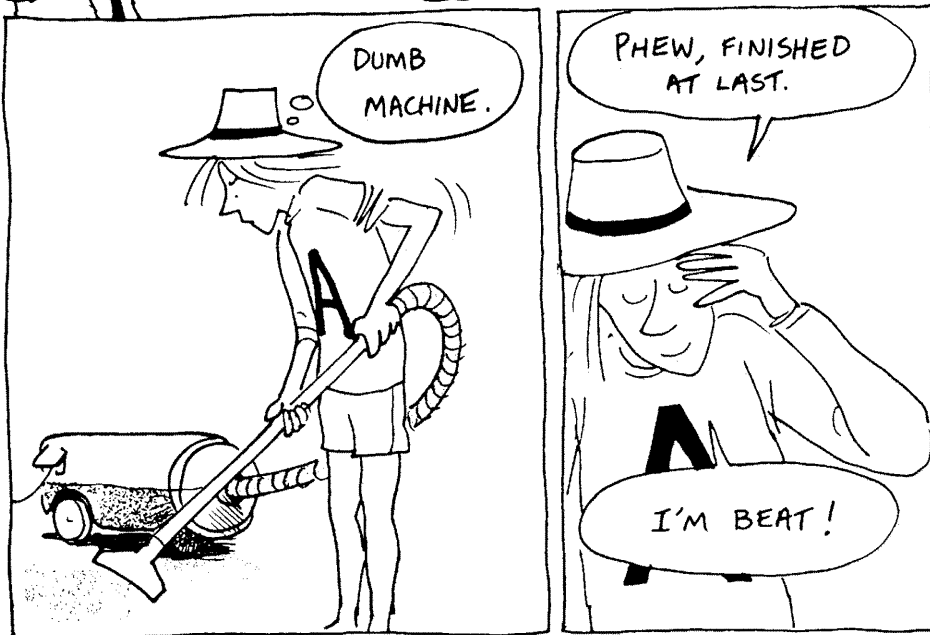


CLOKKITY
CLOK CLOK
CLUNK



WELL, WELL.
YOU HAVE
BEEN BUSY!





PROGRAMMABLE AUTOMATA

I'VE CONVERTED IT INTO A
PROGRAMMABLE CLEANER.

HERE'S THE FAMOUS INVENTOR WITH HIS
PROGRAMMABLE AUTO-VAC. HE IS GOING TO
DEMONSTRATE HIS BRAINCHILD. SEE HOW HE
SETS IT IN MOTION AND STEERS IT WITH THESE LEVERS...

SO WHAT? WHO CARES? WHAT
DIFFERENCE DOES IT MAKE
WHETHER YOU STEER IT WITH YOUR
HANDS, OR FIDDLE ABOUT WITH
LITTLE LEVERS?

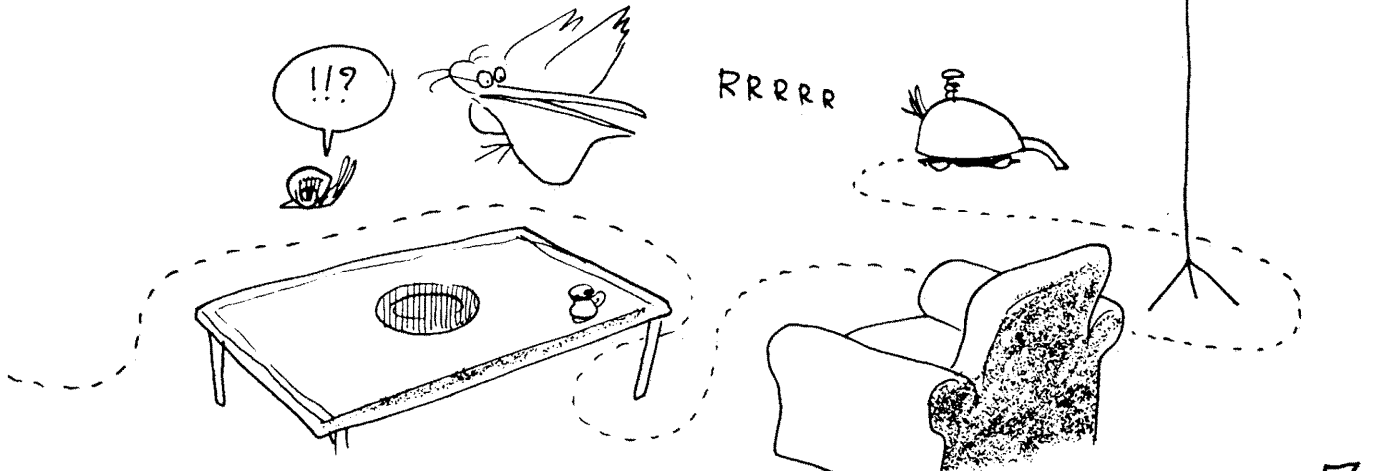
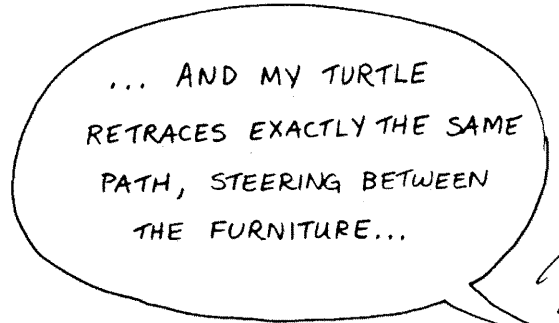
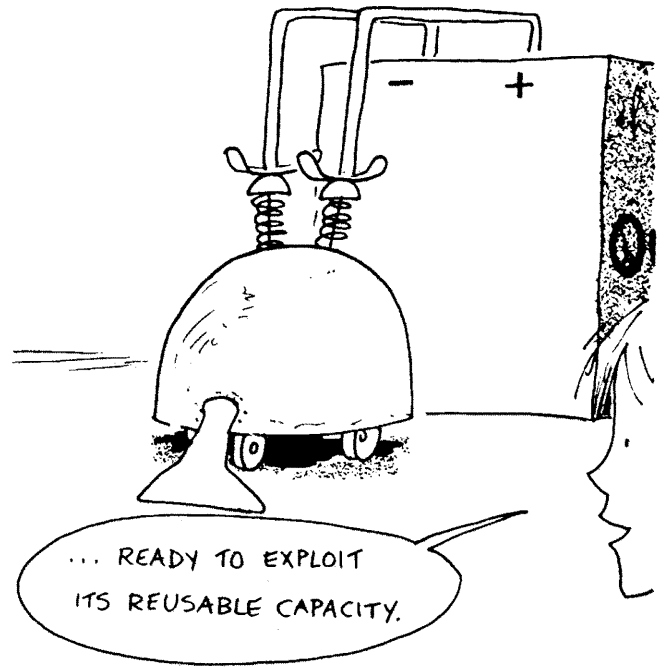
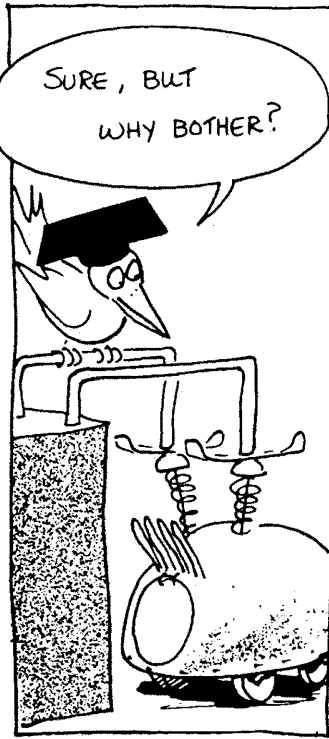
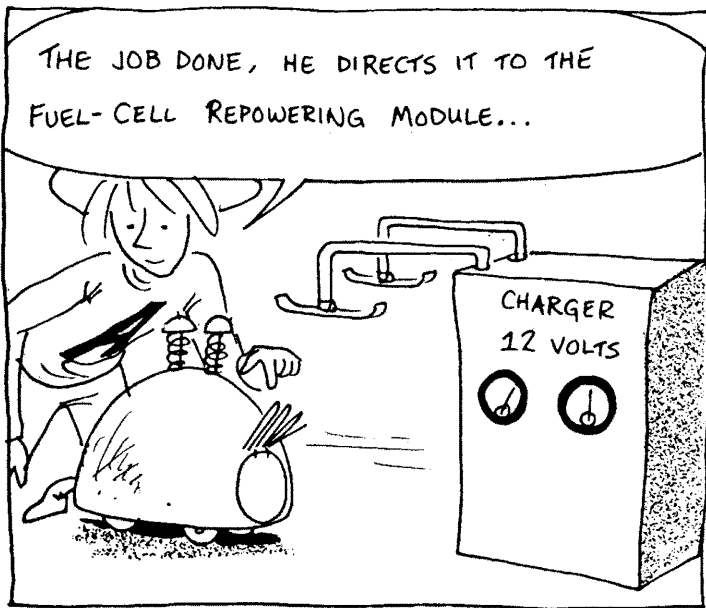
LEFT!
RIGHT!

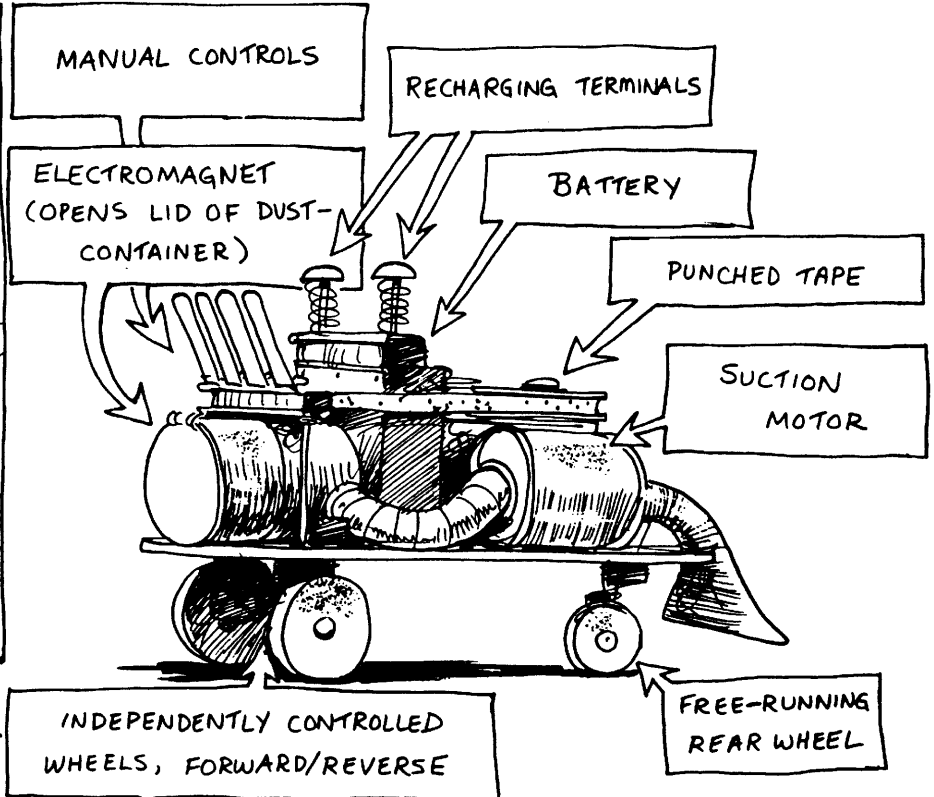
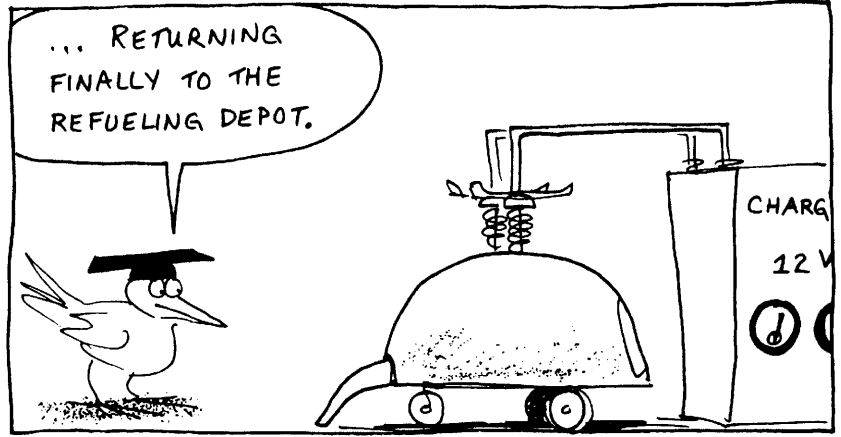
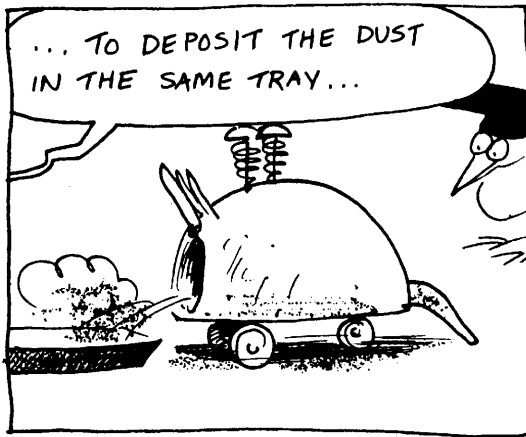
R R R R

THE FAMOUS INVENTOR STEERS HIS TURTLE
TO A TRAY AND MAKES IT EMPTY OUT
ITS DUST-BAG.

WRRRRRA

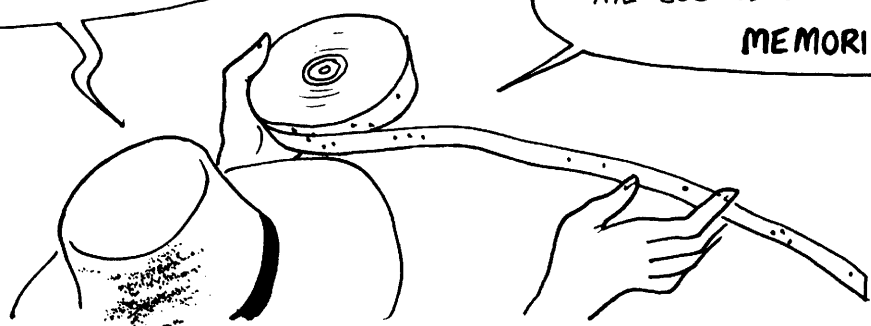
KOF.



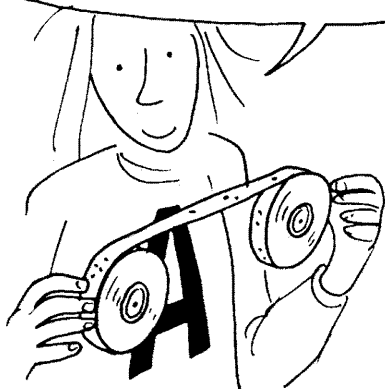


WHEN I OPERATED THE TURTLE MANUALLY, THIS TAPE UNWOUND AT A STEADY RATE. THE COMMANDS THAT I GAVE IT WERE WRITTEN ON TO THE TAPE IN THE FORM OF PUNCHED HOLES.

SO THE STEPS INVOLVED IN THE JOB WERE ALL MEMORIZED.

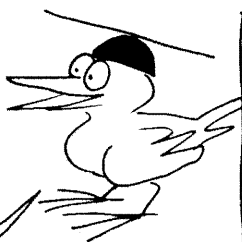


WHEN THE TURTLE RETURNS FOR
REFUELING, THE TAPE REWINDS.

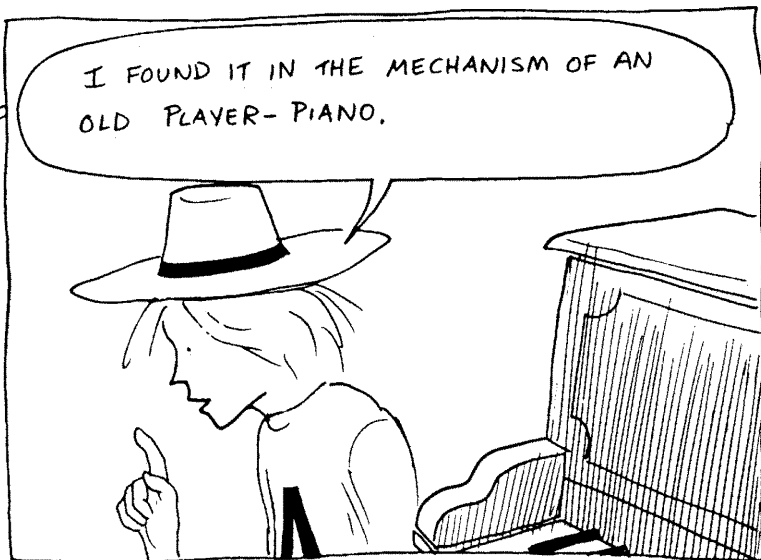


SO NOW YOU CAN MAKE IT WORK THE
OTHER WAY ROUND: THE TURTLE READS THE
INSTRUCTIONS ON THE TAPE AND CARRIES
THEM OUT. BRILLIANT!

WHERE DID YOU
GET THAT?



I FOUND IT IN THE MECHANISM OF AN
OLD PLAYER-PIANO.



!?

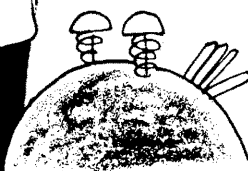
THE DINING-ROOM
VACUUM STAKES,
THIRD RACE!

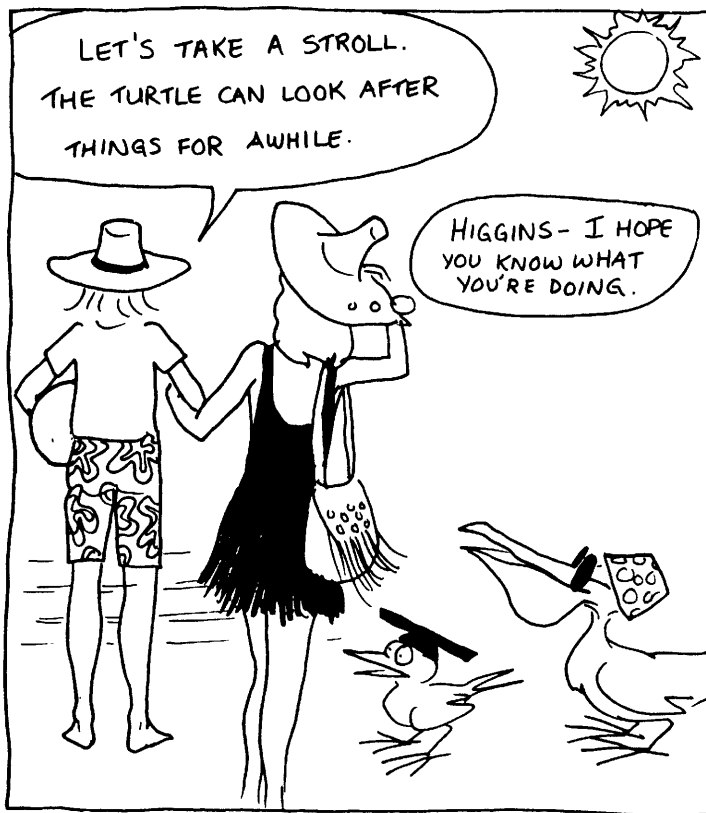
THE FLAG IS
RAISED... THEY'RE
OFF!

OH OH,
OBSTRUCTION ON THE
TRACK! LOOK OUT,
SOPHIE!

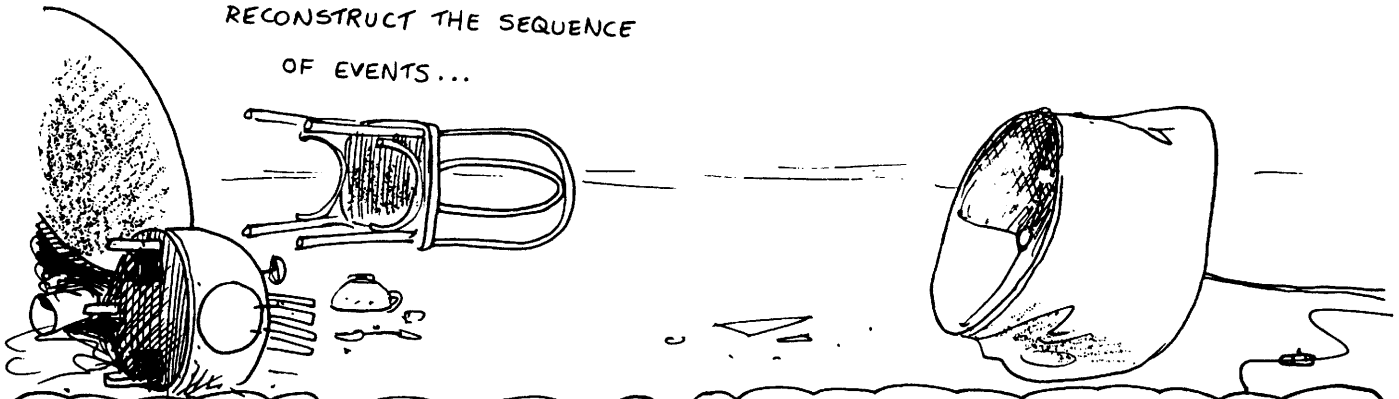


R R R R R R





THE MARVELS OF MODERN
FORENSIC SCIENCE ALLOW US TO
RECONSTRUCT THE SEQUENCE
OF EVENTS...



ALL HAD GONE WELL UNTIL THE
TURTLE HAD ENCOUNTERED THE TAIL
OF A SLEEPING CAT - AN EVENTUALITY
NOT PROVIDED FOR IN ITS PROGRAM...

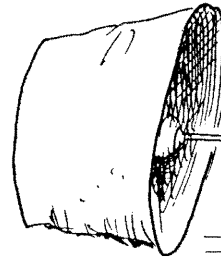
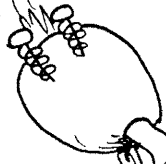


... AND HAD SUCCEEDED IN INGESTING
THE OBSTACLE UP TO ITS MID-POINT.



DURING THE ENSUING PANIC, THE CAT DRAGGED THE VACUUM-CLEANER TURTLE THE LENGTH OF THE APARTMENT, CAUSING A CERTAIN AMOUNT OF INCIDENTAL DAMAGE.

SPLING!

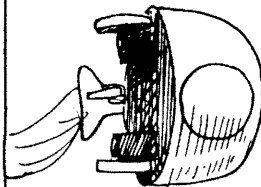


BONK!

TIM-BERRR!



THE BATTERY ACID HAS SPILT AND EATEN HOLES IN THE RUG.



AND THE CONFOUNDED TURTLE'S EATEN MY KNITTING!

I KNOW... I KNOW... I'LL MAKE SURE IT'S ALL CLEANED UP.



PFFFT

CLIP!



THE CAT LEFT A MESSAGE.

"I'M NOT STAYING A
MOMENT LONGER IN THIS
NUTHOUSE. DON'T COUNT ON ME
TO CATCH YOUR MICE. GOODBYE
AND GOOD RIDDANCE."

I THOUGHT MY TURTLE WAS
INTELLIGENT, BUT NOW I SEE HOW
DUMB IT WAS.

BUT HE DIDN'T
GIVE HIS NOTICE!

INPUT-OUTPUT SYSTEMS

HOW DID YOU THINK IT COULD BE INTELLIGENT?
YOU GAVE IT NO WAY OF KNOWING WHAT WAS GOING
ON AROUND IT!

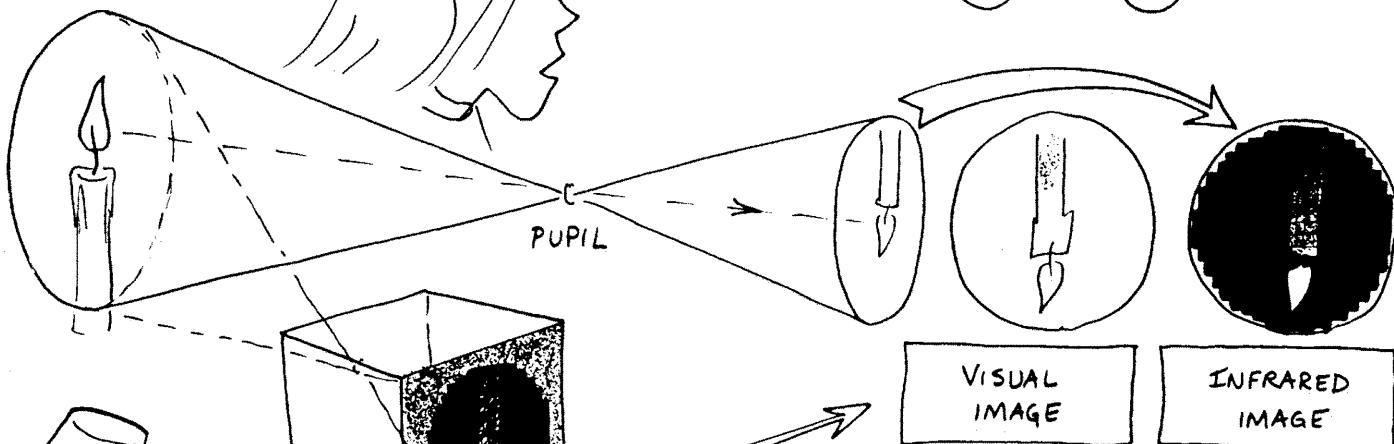
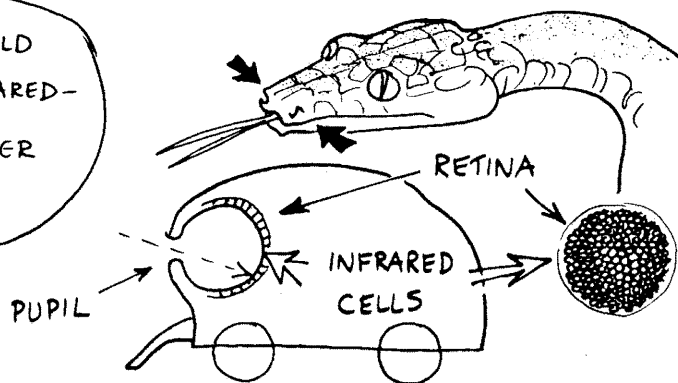
YOU'VE GOT TO GIVE
IT SOME SENSE ORGANS.

YOU'RE RIGHT. THE TURTLE NEEDS TO "SEE"
WHERE IT'S GOING. THIS IS A TINY PHOTOCELL
SENSITIVE TO **INFRARED** LIGHT - THAT IS,
THERMAL RADIATION.

HE MEANS THAT IT REACTS
TO ANY HEAT SOURCE.

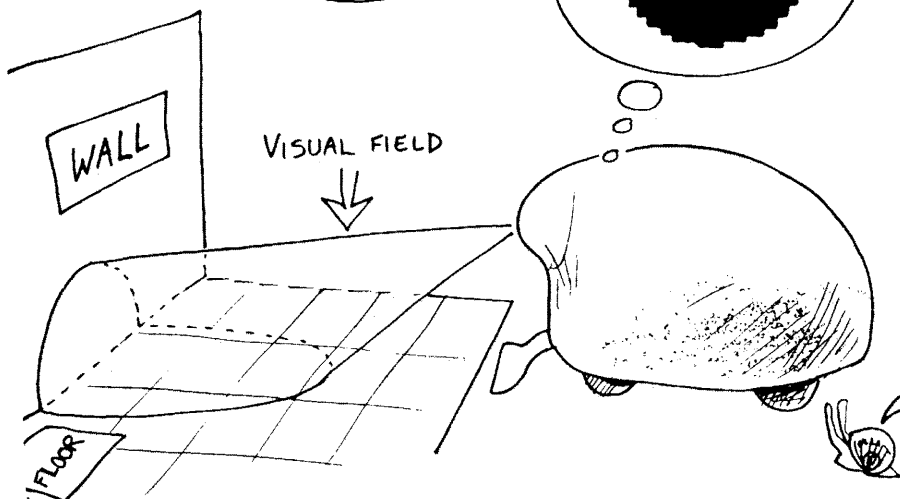
THERMAL
RADIATION

I'LL USE A FEW HUNDRED PHOTOCELLS TO BUILD A RUDIMENTARY "EYE," RATHER LIKE THE INFRARED-SENSITIVE "EYES" THAT SNAKES HAVE ON EITHER SIDE OF THE NOSE.



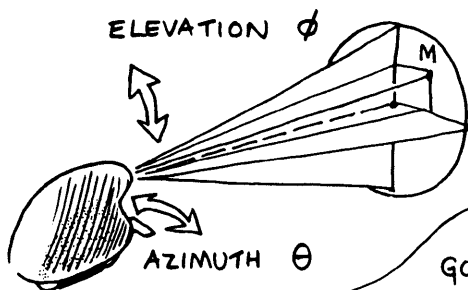
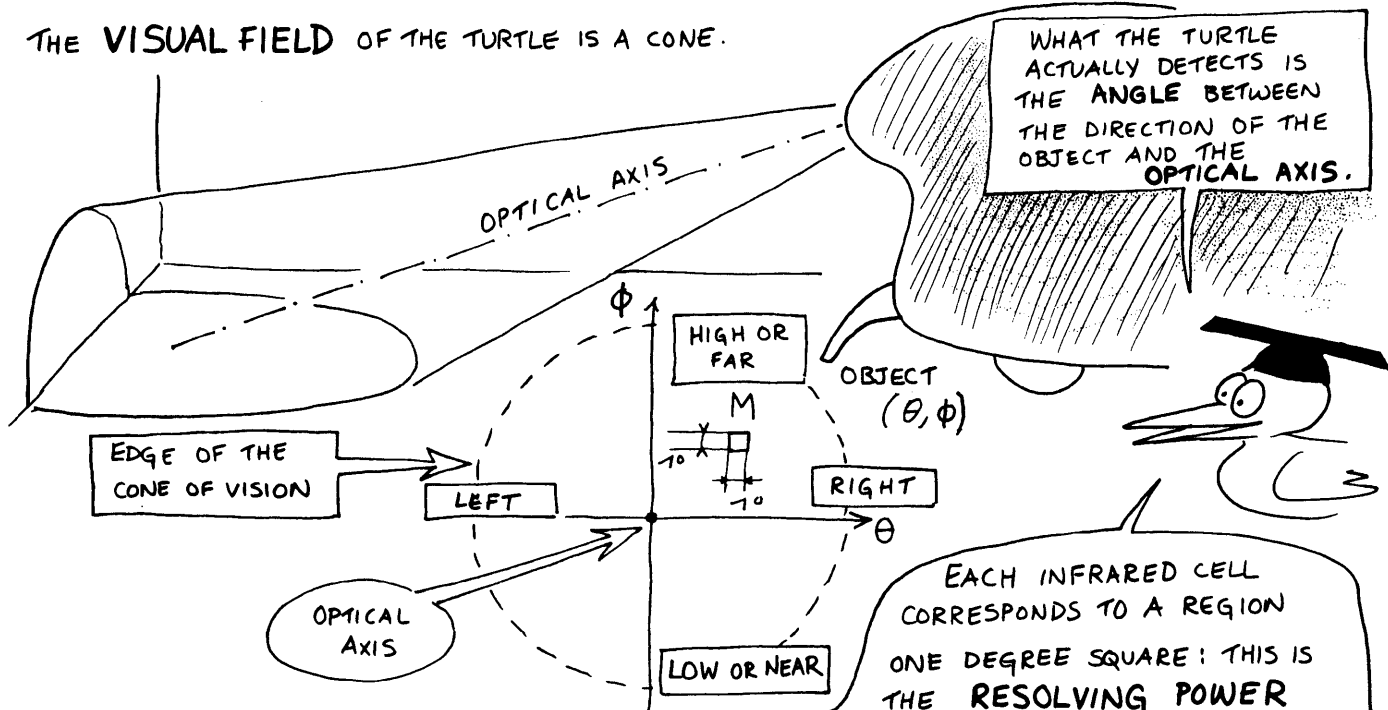
THE TILED FLOOR OF THE APARTMENT IS COLD. IF I ARRANGE FOR THE TURTLE TO TAKE THAT AS ITS ZERO-LEVEL FOR TEMPERATURE, IT WILL SEE THE FLOOR AS A BLACK BACKGROUND.

WALLPAPER'S A BIT WARMER, SO THE WALLS WILL APPEAR TO BE "GREY."



THE IMAGE IN THE BUBBLE HAS BEEN STRAIGHTENED OUT TO KEEP THE EXPLANATION SIMPLE.

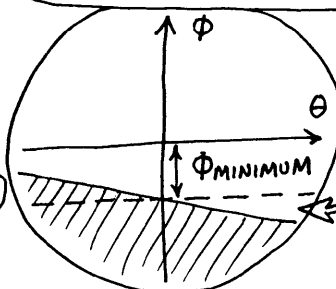
THE VISUAL FIELD OF THE TURTLE IS A CONE.



EACH INFRARED CELL CORRESPONDS TO A REGION ONE DEGREE SQUARE: THIS IS THE RESOLVING POWER OF THE OPTICAL SYSTEM. THE IMAGE IS DIGITIZED, WHICH MEANS THAT IT'S CONVERTED TO A GRID OF TINY SQUARES, WHICH ARE EITHER BLACK, WHITE, OR GREY.

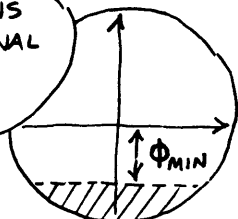
I'VE CHUCKED OUT THE OLD PROGRAM, AND NOW I'M GOING TO GIVE THE TURTLE A SIMPLE **REFLEX** WHICH WILL LET IT AVOID THINGS: "IF ONE PHOTOCELL DETECTS A QUANTITY OF THERMAL RADIATION GREATER THAN SOME **THRESHOLD** VALUE, AND IF THIS SOURCE IS LOCATED BELOW A **HORIZON** (THAT IS, IF THE ELEVATION ϕ OF THE OBJECT IS LESS THAN A VALUE ϕ_{MIN}), THEN THE TURTLE WILL MAKE A QUARTER-TURN TO THE RIGHT."

!?

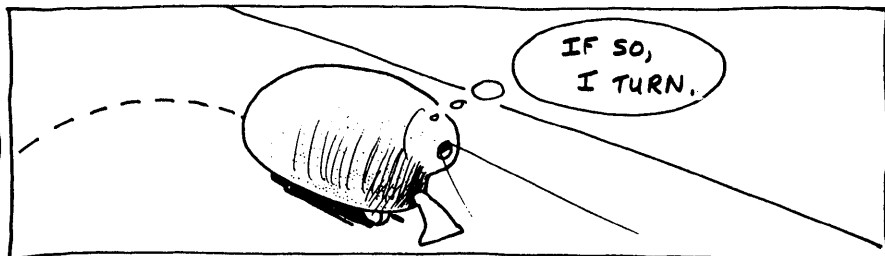


AMOUNT OF HEAT RADIATION GREATER THAN THE THRESHOLD; AND ANGLE ϕ LESS THAN THE HORIZON VALUE ϕ_{MIN} .

WHAT HE MEANS IS, IF THE SIGNAL IS IN THE SHADED ZONE



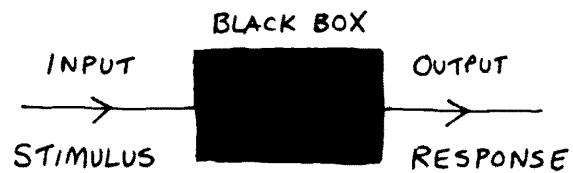
IF SO, I TURN.



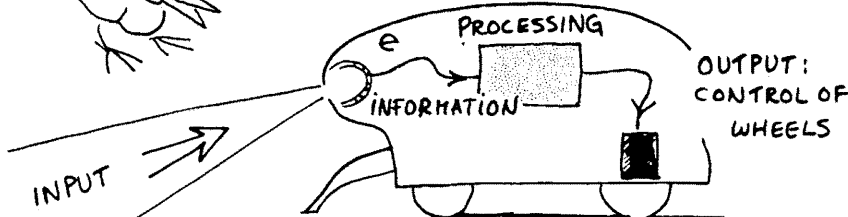
SO NOW THE TURTLE HAS
BECOME AN **INPUT-OUTPUT**
SYSTEM.

A **BLACK BOX**

WHAT'S INSIDE THE
BLACK BOX?



A **PROGRAM** THAT LETS IT
ANALYZE THE **INPUT DATA** (THE
INFORMATION PROVIDED BY THE "RETINA") AND
DECIDE WHAT **RESPONSE** TO MAKE;
EITHER GO STRAIGHT AHEAD, OR MAKE A
QUARTER-TURN RIGHT.



THIS TIME THE FAMOUS INVENTOR WILL REALLY CLEAN UP! HIS TURTLE
WILL AVOID THE WALLS, AND ALSO THE FURNITURE, BECAUSE THEY'RE WARMER
THAN THE TILED FLOOR.

GREAT! I'VE CRACKED IT! IT'S
ALL PERFECTLY SIMPLE, AND NOW I
CAN STOP WORRYING.

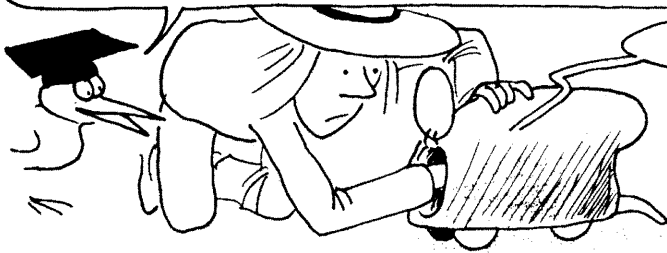
ARCHIBALD!

OH OH

THE TURTLE'S SWOLLERED TIRESIAS!

EH? HOW DID THAT HAPPEN?

TIRESIAS IS A COLD-BLOODED CREATURE, AND HIS FOOT MAKES GOOD THERMAL CONTACT WITH THE FLOOR. TO CUT A LONG STORY SHORT, HE HAS THE SAME TEMPERATURE AS THE FLOOR, SO AS FAR AS THE TURTLE IS CONCERNED... HE'S INVISIBLE!

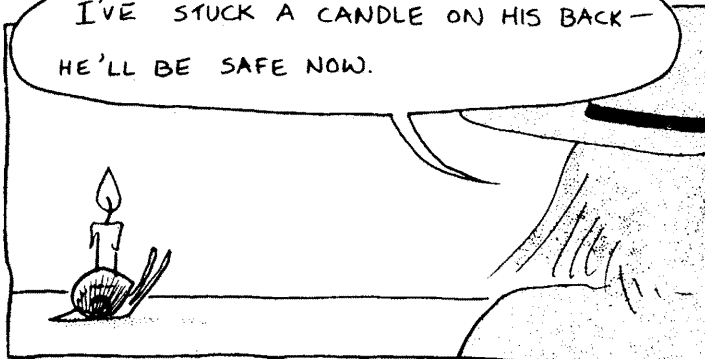


CAREFUL THERE!

AAAAA...CHOOOOO!



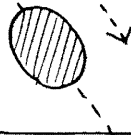
I'VE STUCK A CANDLE ON HIS BACK—
HE'LL BE SAFE NOW.



HAVE YOU NOTICED THAT WHEN THE
TURTLE ENCOUNTERS THE WALL
OBLIQUELY, LIKE THIS, IT HAS TO MAKE
TWO QUARTER TURNS? WE CAN DO
BETTER THAN THAT!



WALL



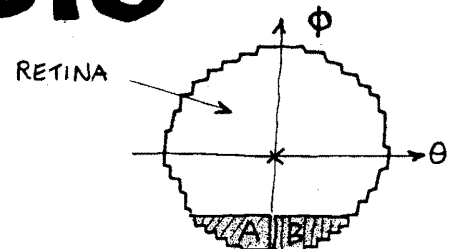
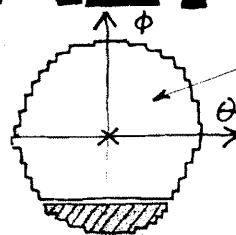
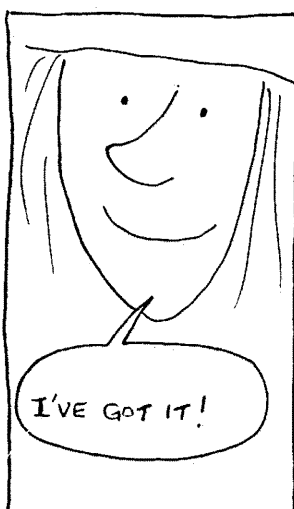
YES... IT'D BE MORE LOGICAL TO HAVE IT MAKE A LEFT TURN INSTEAD...

SIGNAL ANALYSIS

BUT HOW?



I'VE GOT IT!



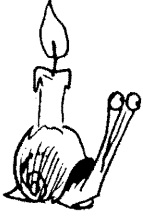
OLD PROGRAM:

IF A WARM OBJECT
APPEARS IN THE SHADED
ZONE, MAKE A
QUARTER TURN TO
THE RIGHT.

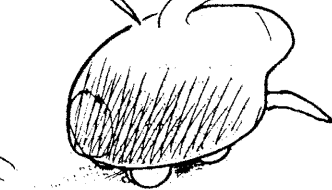
NEW PROGRAM:

IF A WARM OBJECT
APPEARS IN SECTOR A,
MAKE A QUARTER TURN
TO THE RIGHT. IF IN
SECTOR B, MAKE A
QUARTER TURN TO THE LEFT.

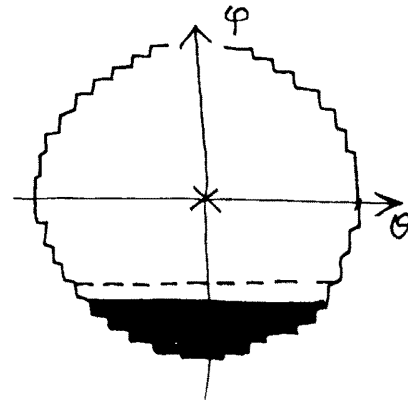
YES... BUT WHAT IF
IT'S DIRECTLY IN FRONT?



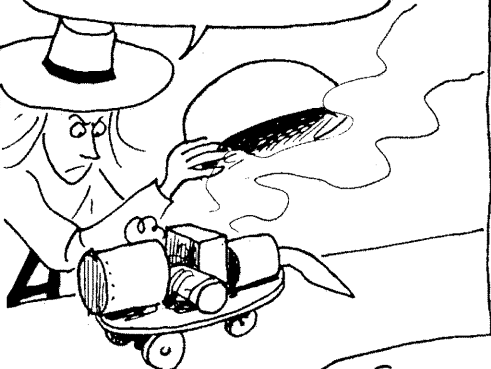
!!!!



ARCHIE -
H'IT'S GOIN' UP IN SMOKE!



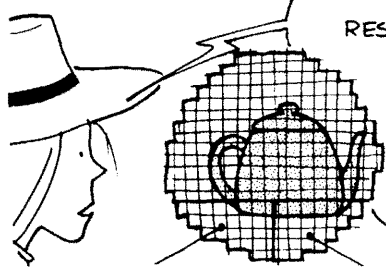
SILLY BEAST!



THE ANSWER IS A SMALL ADJUSTMENT:
IF THE SIGNAL IS SIMULTANEOUSLY TO THE LEFT
AND RIGHT, THEN TURN TO THE RIGHT.

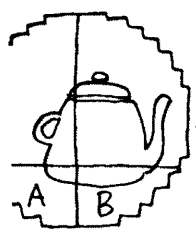


SOPHIE, I THINK I CAN IMPROVE THE WAY THE TURTLE
RESPONDS TO THE SIGNALS RECEIVED BY ITS INFRARED EYE.
IF THIS IS AN OBJECT IN ITS FIELD OF VISION, ALL I HAVE
TO DO IS COUNT THE NUMBER OF CELLS IN SECTOR A
(NEAR AND LEFT) AND COMPARE WITH THE NUMBER IN
B (NEAR AND RIGHT).

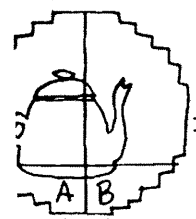


SECTOR A

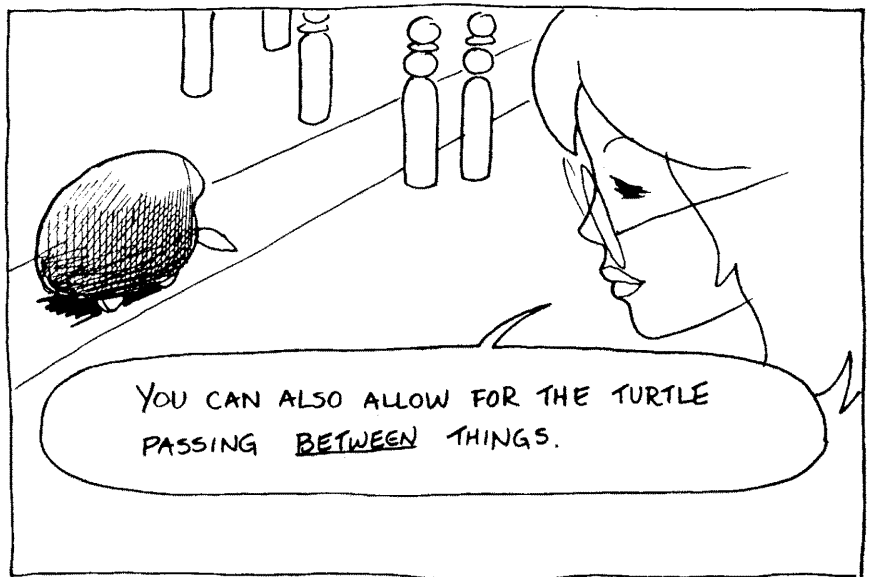
SECTOR B



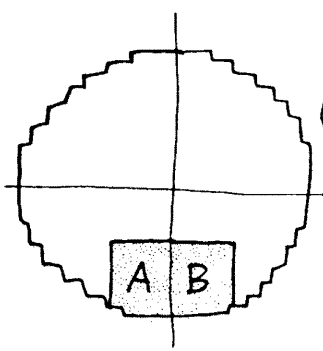
MOVE TO
THE RIGHT



MOVE TO
THE LEFT



YOU CAN ALSO ALLOW FOR THE TURTLE
PASSING BETWEEN THINGS.



ALL I HAVE TO DO IS CUT SOME PIECES OFF THE TWO SECTORS A AND B ON THE RETINA.

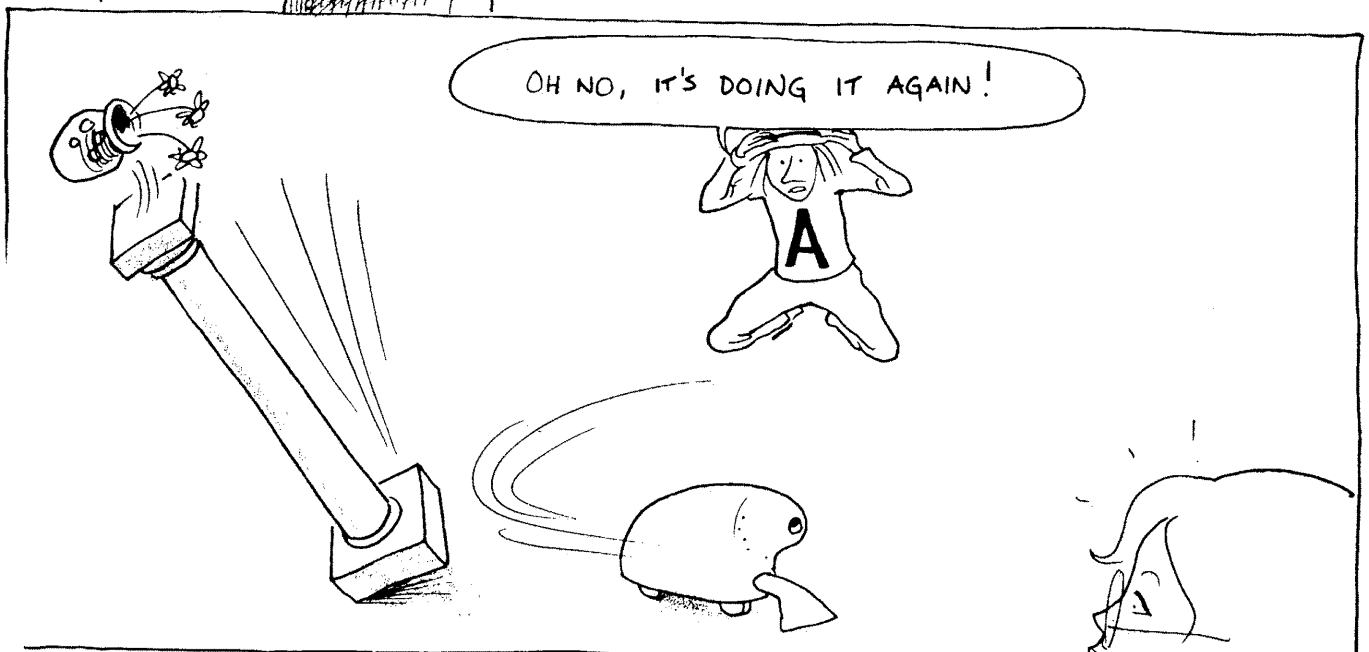


RESPONSE TIME

THE MAIN POINT ABOUT MACHINES IS THAT THEY CAN GET THINGS DONE QUICKLY.



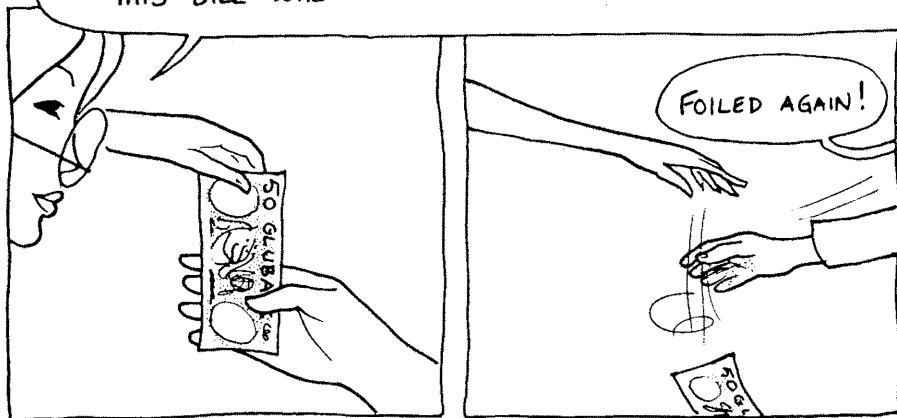
I'LL TURN IT UP TO THE HIGHEST SPEED. THAT WAY, THE CLEANING WILL BE DONE IN RECORD TIME.



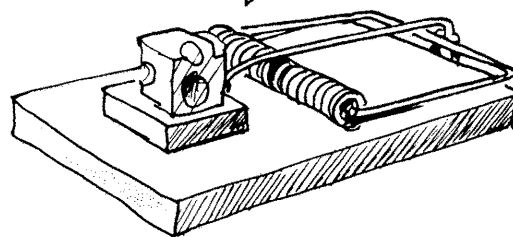
ARCHIE, IT'S NO GOOD EXPECTING A MACHINE TO REACT INSTANTANEOUSLY. BETWEEN THE INPUT AND THE OUTPUT YOU MUST ALLOW A RESPONSE TIME WHICH IS CHARACTERISTIC OF THE SYSTEM.



IT'S YOUR OWN RESPONSE TIME THAT PREVENTS YOU FROM CATCHING THIS BILL WHEN I LET IT DROP.



DANGER: INPUT-OUTPUT SYSTEM WITH SHORT RESPONSE TIME.



YES, YES, IT'S SPEED I NEED!

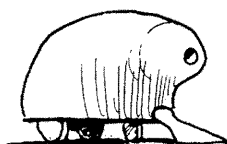


ooo.

CLEANING THE APARTMENT GOBBLES UP LOTS OF ENERGY. THE TURTLE'S BATTERIES ARE FLAT.



IT NEEDS TO BE ABLE TO GUIDE ITSELF TO A RECHARGING SYSTEM.



YES, BUT HOW?



SERVOMECHANISMS

WHEN THE BATTERY STARTS TO GO FLAT, THE VOLTAGE ACROSS ITS TERMINALS DROPS. IT'S EASY TO ADD TO THE PROGRAM SOMETHING LIKE:

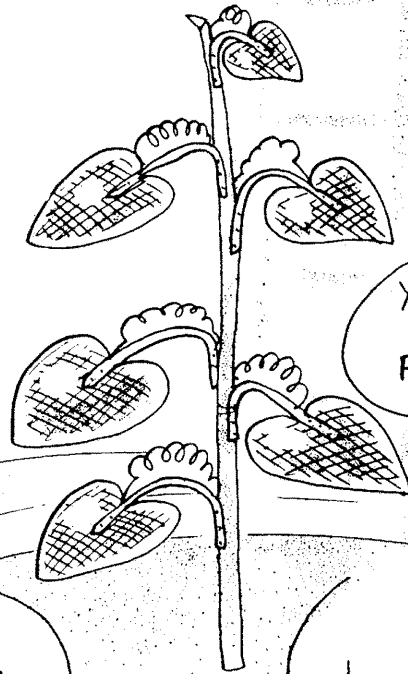
IF THE VOLTAGE BECOMES LOWER THAN... SO MANY VOLTS,

THEN GO AND GET CHARGED UP AGAIN.

BUT THE PROBLEM IS: HOW DO YOU GUIDE THE TURTLE TO THE RIGHT PLACE?



WHILE I'M WAITING FOR INSPIRATION, I'LL MAKE A UNIT THAT RECHARGES ITSELF USING SOLAR PANELS.



YOU MIGHT CALL IT A POWER PLANT!



MAYBE I COULD GUIDE THE TURTLE BY USING THIS HEATING COIL... TROUBLE IS, IT TURNS AWAY FROM HEAT.



WHAT YOU NEED IS A LITTLE FEEDBACK.

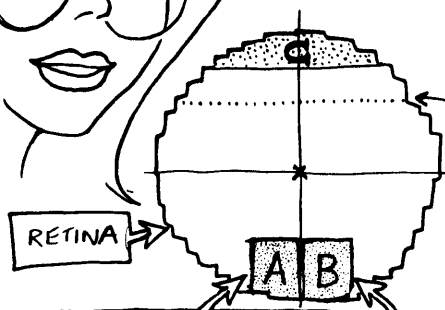
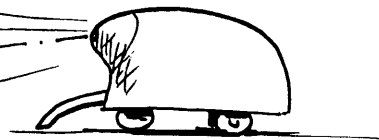


THE TURTLE DOESN'T HAVE TO THINK OF THE COIL AS AN OBSTACLE, YOU KNOW. WHY DON'T YOU PLACE IT UP HIGH, TO ACT AS A **BEACON** ?



COIL: HEAT SOURCE
HORIZON

OPTICAL AXIS



AVOID OBSTACLES IN THESE SECTORS.

NAR THE 'EATIN' COIL SHOWS UP IN SECTOR G, AT THE TOP O' THE H'EYEBALL. H'EYE UP, YER MIGHT SAY!



NOW IT'S EASY TO REPROGRAM THE TURTLE: IF THE CHARGE IN THE BATTERY FALLS BELOW SO MANY VOLTS THEN LOOK FOR THE COIL. THERE ARE TWO POSSIBILITIES. EITHER THE COIL IS ALREADY IN THE FIELD OF VISION, AND THE TURTLE CAN GO AFTER IT; OR IT'S NOT, IN WHICH CASE THE TURTLE STOPS, AND REVOLVES, UNTIL THE BEACON APPEARS.

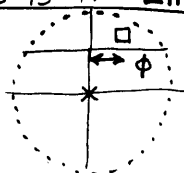
?



AS SOON AS THE TARGET COMES INTO VIEW, THE TURTLE CAN HOME IN ON IT BY FOLLOWING THIS PROGRAM:

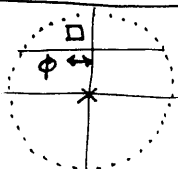
TURN TOWARDS THE TARGET, BY AN AMOUNT PROPORTIONAL TO THE ANGULAR DEVIATION ϕ BETWEEN THE TARGET AND THE CURRENT DIRECTION OF MOTION. THIS IS A **LINEAR SERVOMECHANISM**.

SIGNAL TO RIGHT



TURN TO THE RIGHT

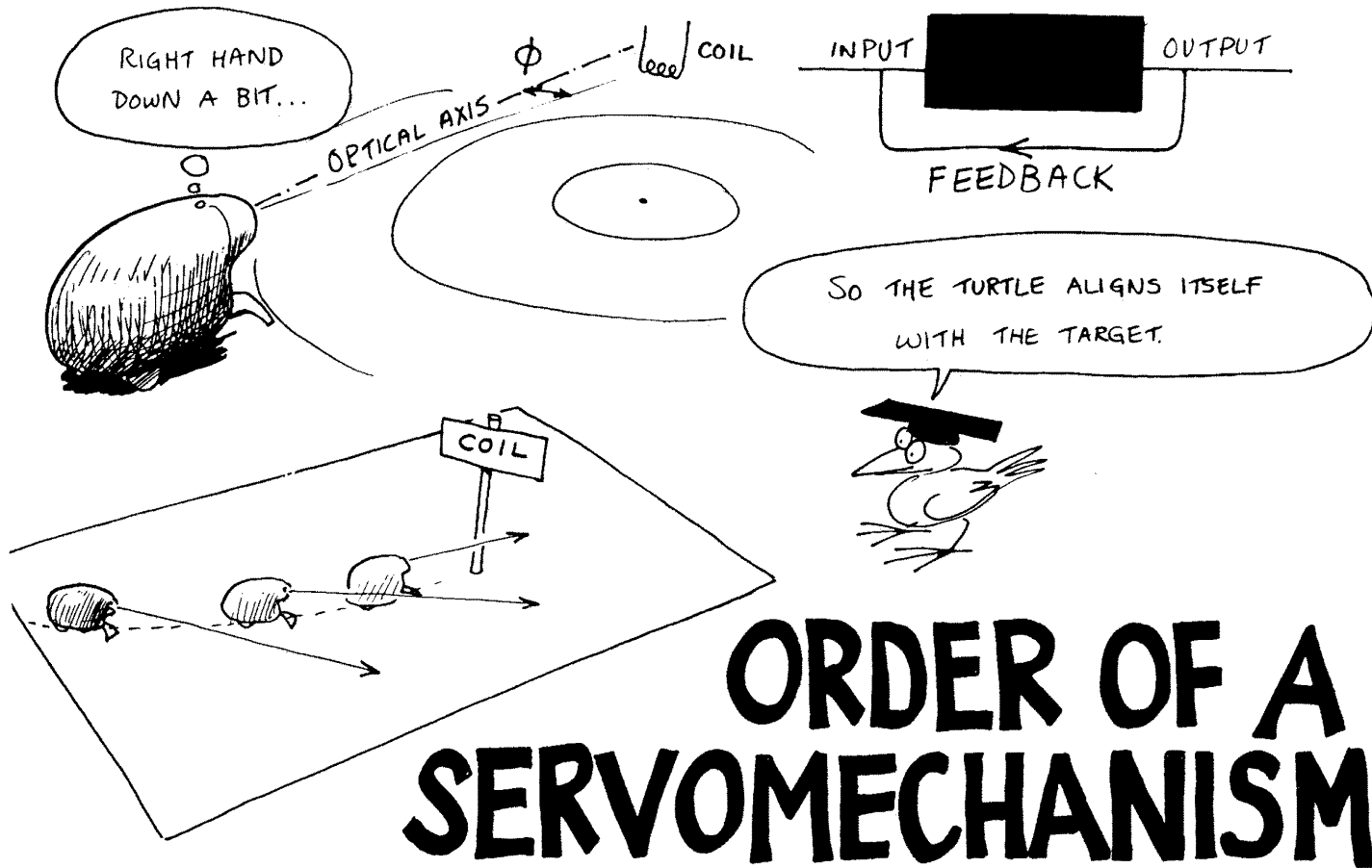
SIGNAL TO LEFT



TURN TO THE LEFT

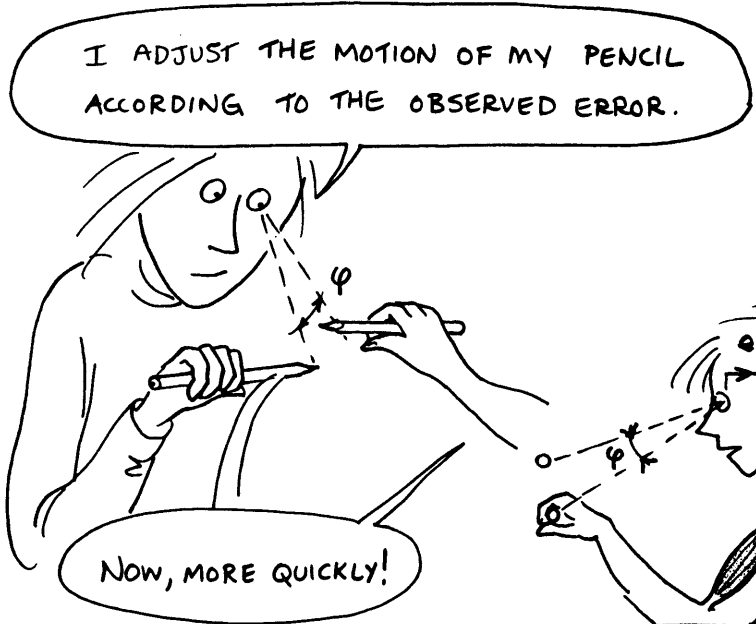


AS THE TURTLE STEERS TOWARDS THE TARGET, THE ERROR ϕ CHANGES.
SO ϕ IS ACTING BOTH AS CAUSE AND AS EFFECT. THAT'S FEEDBACK!

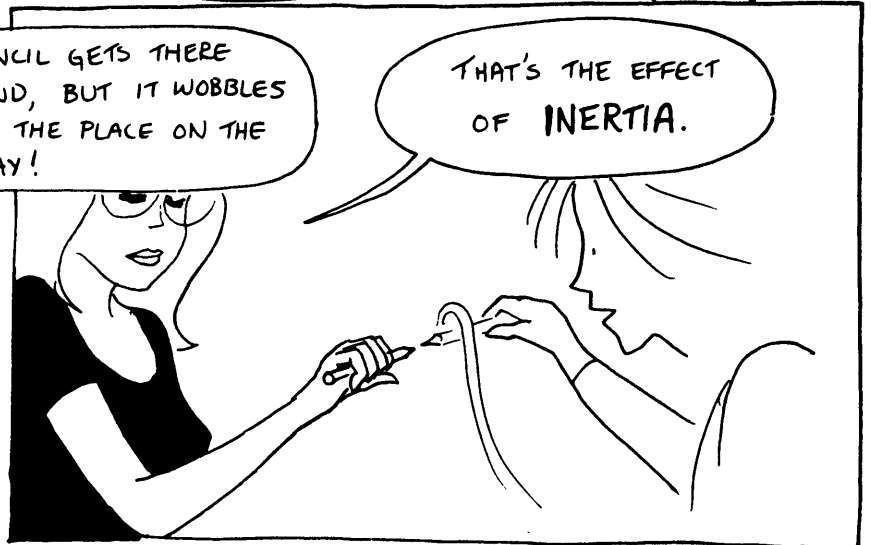


NOW, ARCHIE, LET'S PLAY A GAME. WHEN I GIVE THE SIGNAL, I WANT YOU TO PLACE THE POINT OF YOUR PENCIL NEXT TO MINE.



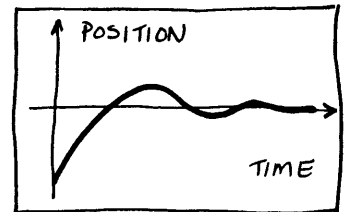
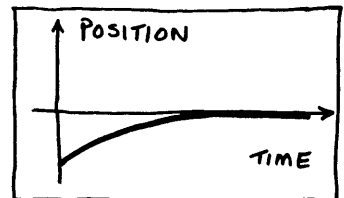


THE PENCIL GETS THERE IN THE END, BUT IT WOBBLES ALL OVER THE PLACE ON THE WAY!

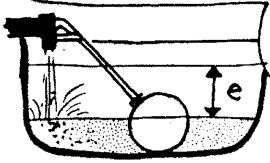


IN A FIRST ORDER SYSTEM, THE OUTPUT COMMANDS ACT DIRECTLY ON THE SPEED, WITHOUT ANY INERTIA. THERE ARE NO OSCILLATIONS.

IN A SECOND ORDER SYSTEM, THE OUTPUT COMMANDS ACT ON THE ACCELERATION BY WAY OF A FORCE. INERTIA LEADS TO OSCILLATIONS.



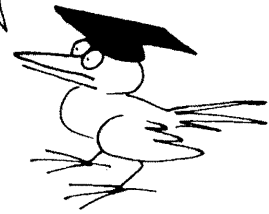
HUMANS ARE SECOND ORDER SYSTEMS. A GOOD EXAMPLE OF A FIRST ORDER SYSTEM IS A CISTERN.



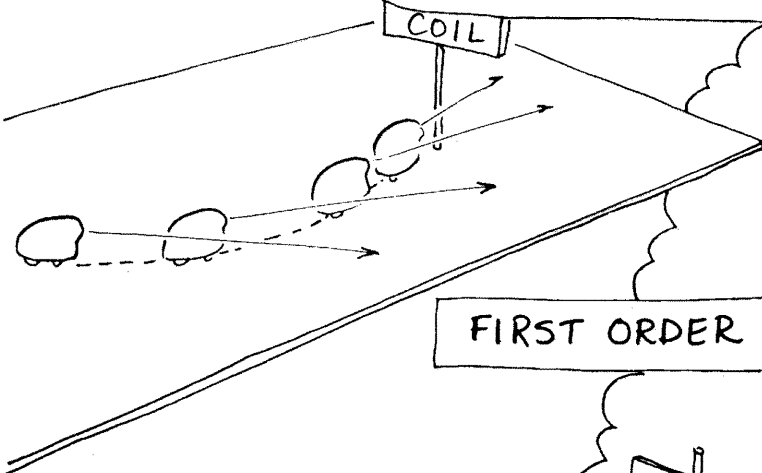
THE SPEED AT WHICH WATER RISES IS PROPORTIONAL TO THE DIFFERENCE FROM ITS FINAL POSITION.



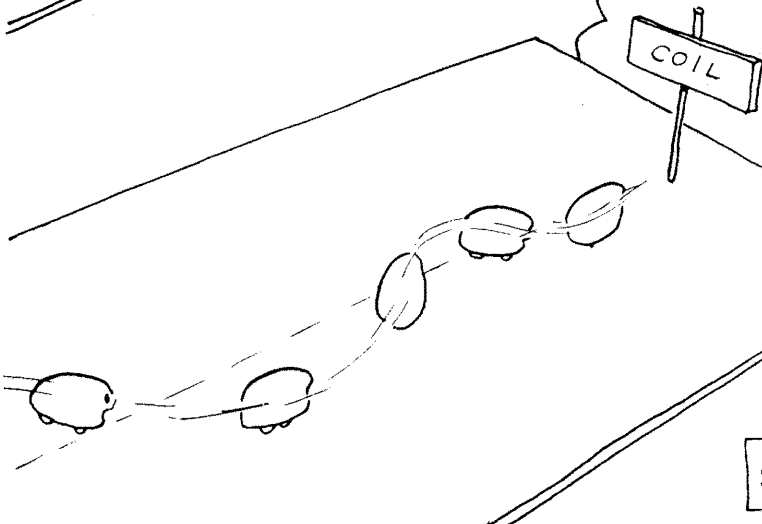
WIV A FIRST H'ORDER CISTERN,
THE WATER DON'T WOBBLE!



AT LEAST, THAT'S THE THEORY. BUT IN THE PHYSICAL NATURE OF THINGS, THERE'S ALWAYS SOME INERTIA PRESENT; AND IF YOU PUSH A BIT TOO HARD, IT SHOWS UP. SUCH A SYSTEM SEEMS TO BE FIRST ORDER BUT IS REALLY ... SECOND ORDER.



FIRST ORDER



SECOND ORDER

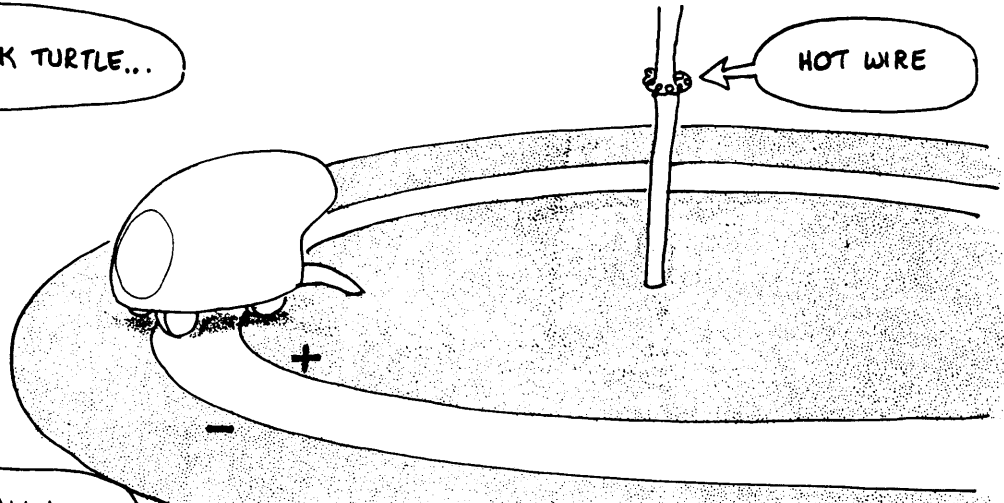


SOPHIE, LENNY THE PELICAN SAYS I'M SO SLOW THAT I'M INSENSITIVE TO INERTIA, AND I'LL NEVER BE MORE THAN A MERE FIRST ORDER SYSTEM.



CONTROL AND HOMEOSTATIC SYSTEMS


BUT NOW LET'S TALK TURTLE...



ARCHIE'S IDEA IS REALLY QUITE CLEVER. THE ELECTRIC TREE - THE "POWER PLANT" - GENERATES A FLOW OF CURRENT BETWEEN TWO CIRCULAR ELECTRODES. THESE ARE THE TURTLE'S WHEELS, COATED IN COPPER TO ENSURE GOOD CONTACT. ONCE THE BACK WHEEL MAKES CONTACT WITH THE ANODE AND THE FRONT WHEELS WITH THE CATHODE, THE TURTLE STOPS AND RECHARGES ITS BATTERY. WHEN IT'S FULLY CHARGED, THE TURTLE TURNS ROUND AND WANDERS OFF AGAIN, REFUELED. AS LONG AS THE CHARGE IN THE BATTERY IS REASONABLY LARGE, THE TURTLE IGNORES THE POWER PLANT, AND ITS GUIDING HOT WIRE, COMPLETELY.

BURP!





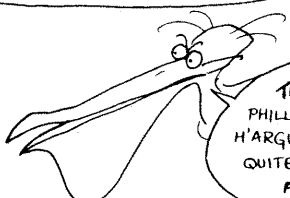
YOU DO JUST THE SAME - YOU STOP TO EAT WHEN THE PRESSURE ON THE WALL OF YOUR STOMACH DROPS BELOW A THRESHOLD VALUE.



ME... I?


STOMACHS WORK JUST LIKE CISTERNS.

YOU MEAN, CISTERNS WORK JUST LIKE STOMACHS.



THESE PHILLYS OFICKLE H'ARGUMENTS CAN GET QUITE DISGUSTIN' AT TIMES.

SYSTEMS LIKE THESE TRY TO MAINTAIN THEIR DEFINING PARAMETERS IN BETWEEN A MINIMAL AND MAXIMAL VALUE.



I SEE. SO WHEN I EAT OR DRINK, I'M ATTEMPTING TO MAINTAIN THE QUANTITIES OF SUGARS AND SALTS IN MY BODY, BETWEEN MINIMAL AND MAXIMAL VALUES.

ARE YOU TELLING ME THAT MAN
IS JUST A MACHINE?

IF I WERE YOU, I'D SAY IT THE
OTHER WAY ROUND. A MACHINE IS LIKE
A MAN.

TECHNOLOGY WORKS BY PERFECTING
OR EXTENDING WHAT GOES ON IN THE
NATURAL WORLD.

ARTIFICIAL
TOOTH

ARTIFICIAL HAIR

NATURAL HAIR

OWN ORIGINAL TEETH

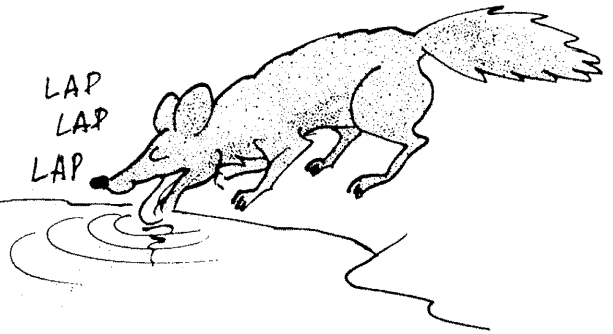
TO BEGIN WITH, WE COPIED THE FORMS
OF LIVING THINGS. NOW WE'RE COPYING
THEIR **BEHAVIOR**

RAPID-RESPONSE
INPUT-OUTPUT SYSTEM

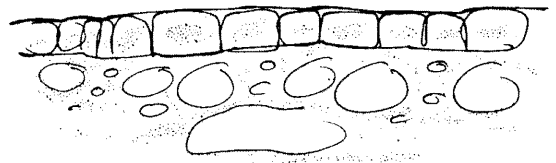
A LIVING CREATURE IS, AMONG OTHER THINGS, A FANTASTIC SELF-REGULATING HOMEOSTATIC MACHINE: MAINTAINING THE BALANCE OF ITS WATER, MINERALS, BLOOD COMPOSITION, TISSUES... EVEN ITS SHAPE.



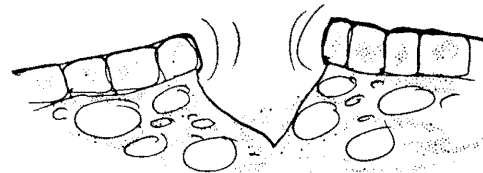
LAP
LAP
LAP



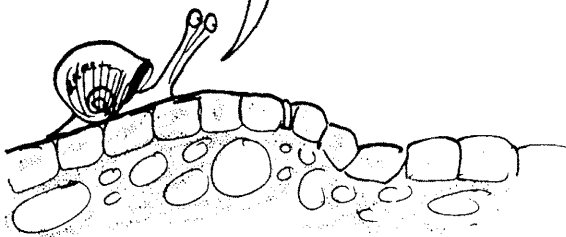
THE GROWTH OF SKIN CELLS IS INHIBITED BY CONTACT.



ANY DETECTABLE CHANGE IN ITS STATE FROM THE NORMAL VALUES DISTURBS THE NATURAL BALANCE.



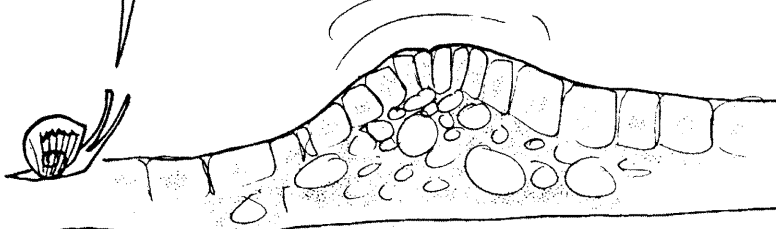
ANY DEFECT IN THE NATURAL BODY-ARMOR TRIGGERS OFF CELL-DIVISION AROUND THE EDGES OF THE CUT.



THE GROWTH IS INHIBITED ONCE CONTACT IS REESTABLISHED.



IF THE MECHANISM STOPS TOO SLOWLY, THE
SCAR WILL BULGE.

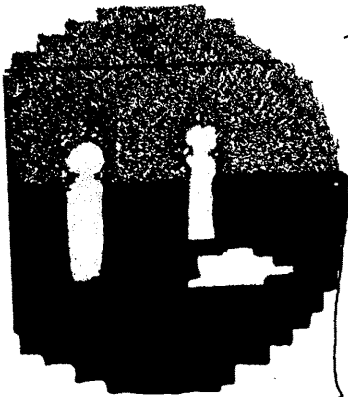
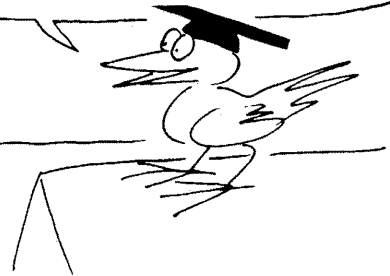


NAR WOT
YER MAKIN'?

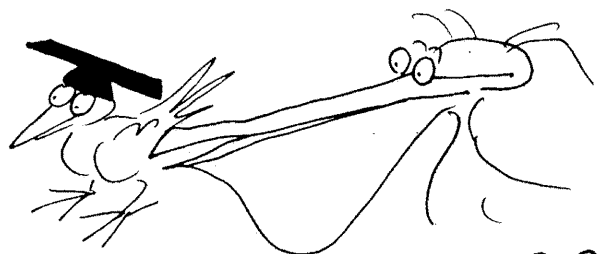
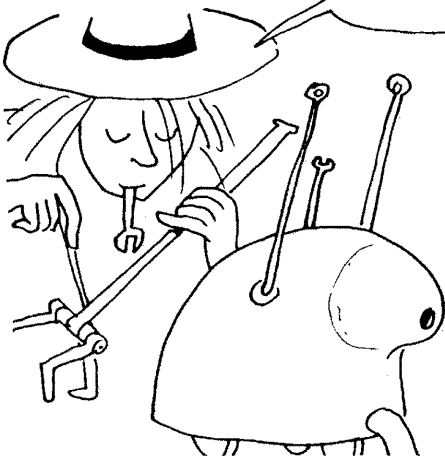
SOPHIE TOLD ME TO GET RID OF ALL
THE MICE IN THE HOUSE. I'M GOING
TO CATCH THEM.

I'VE GIVEN MY TURTLE
A PREDATION ARM AND A
PURSUIT SYSTEM, ALL USING
THE INFRARED EYE.

MICE ARE WARM-BLOODED: 107°

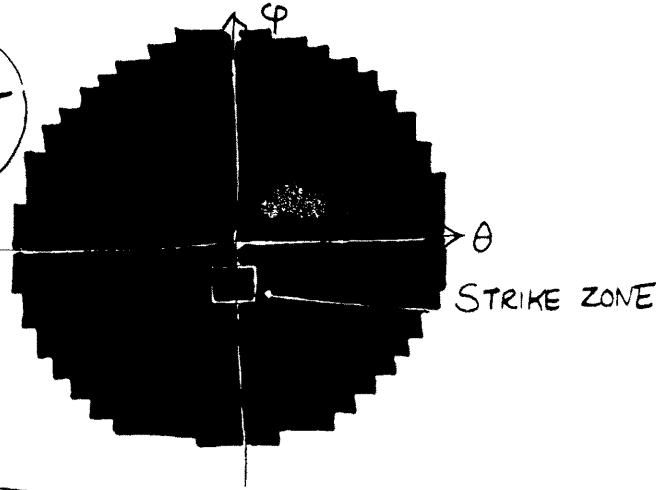


IT'S A MATTER OF THRESHOLDS AGAIN. THE FLOOR
IS BLACK, THE WALLS AND THESE BOWLING PINS ARE
GREY, AND THE MICE WHITE. ALL I HAVE TO DO IS
PROGRAM THE TURTLE TO CHASE AFTER ANY BRIGHT
OBJECT (EXCEPT IN SECTOR G, WHICH IS RESERVED
FOR THE HOT WIRE BEACON ON THE POWER PLANT).



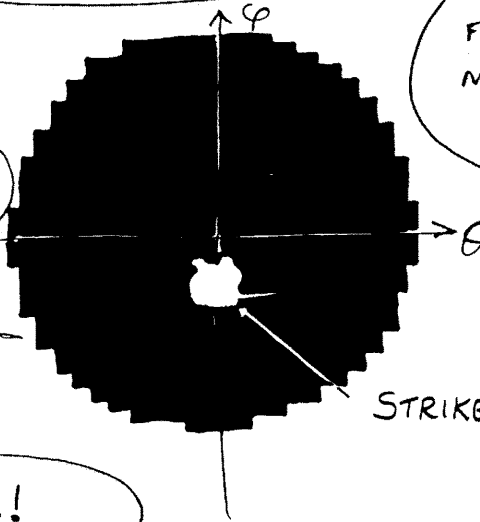
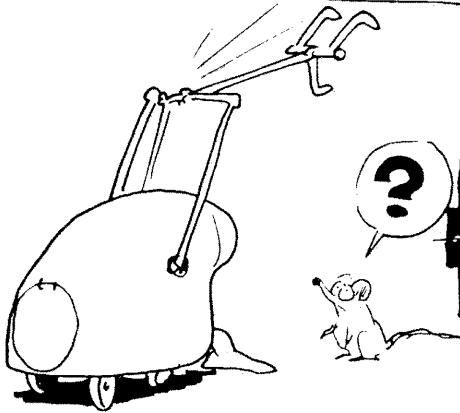
LOOK - IT'S SPOTTED
A MOUSE.

WHAT ON
EARTH IS THAT
THING?



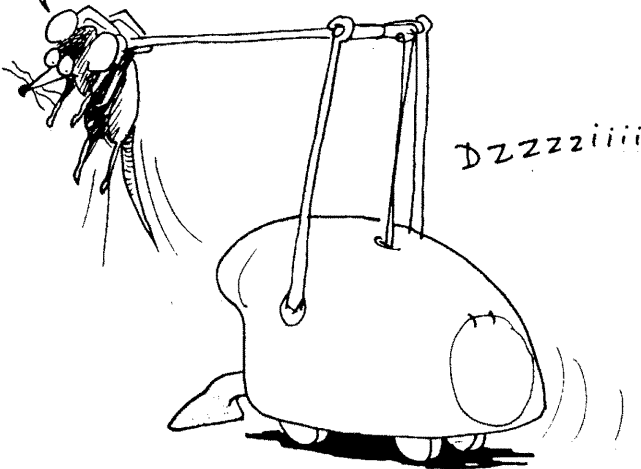
IT'S ALREADY ATTAINED
POUNCE POSTURE.

NOW IT MOVES
FORWARD UNTIL THE
MOUSE IS IN THE
STRIKE ZONE.



HEY! LEGGO!

FOUL BALL!



THE CLOCK
STRUCK ONE, THE
MOUSE STRUCK
OUT...



ARCHIBALDDDD!!

WOOPS

ME?

WILL YOU MAKE IT LET GO
OF MY CUP - OR WHAT'S LEFT
OF IT?

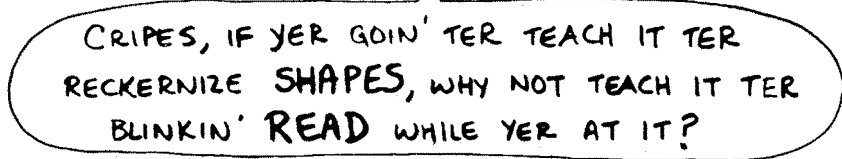
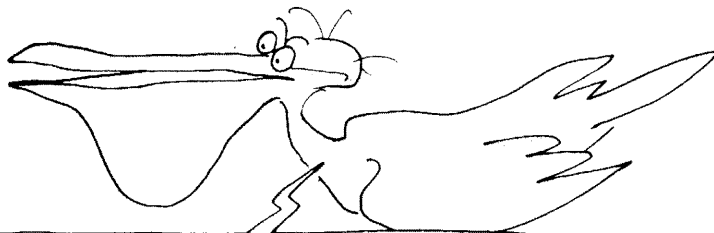
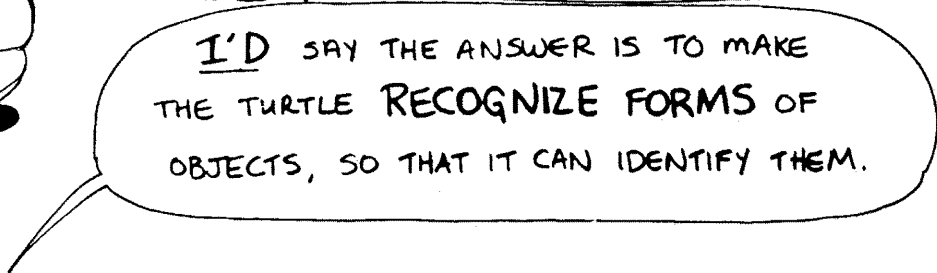
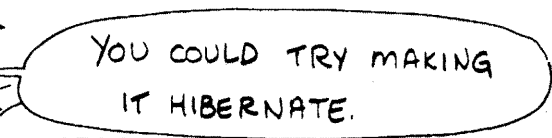
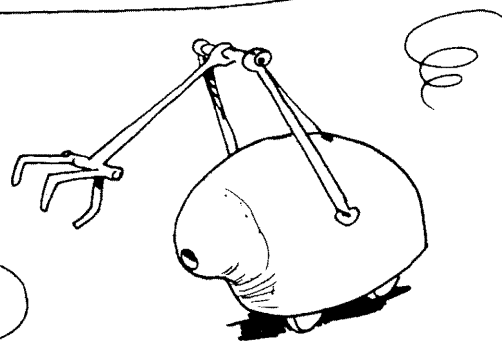
OH MY LORD - IT CAN'T TELL
THE DIFFERENCE BETWEEN A MOUSE
AND A CUP OF WARM COFFEE.

DO YOU
HAVE SANKA?

IT'S THE SAME
PROBLEM THAT SNAKES
HAVE WHEN THEY GO
HUNTING AT NIGHT.

NOT ONLY THAT - THE TURTLE WILL GET
CONFUSED BETWEEN A NEARBY BOWLING PIN AND A
DISTANT MOUSE (THE INTENSITY OF RADIATION VARIES
AS THE INVERSE SQUARE OF THE DISTANCE).

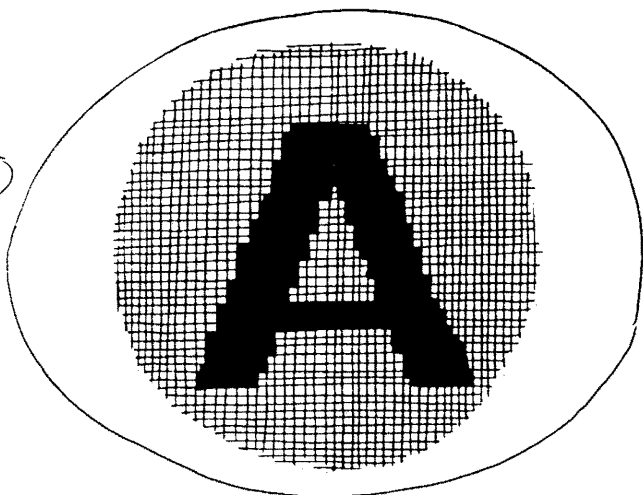
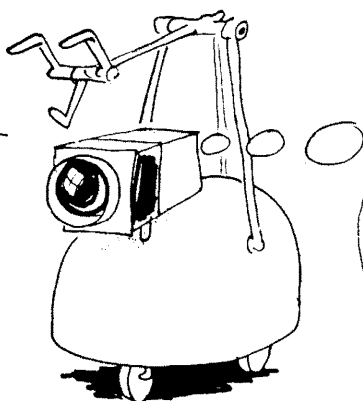
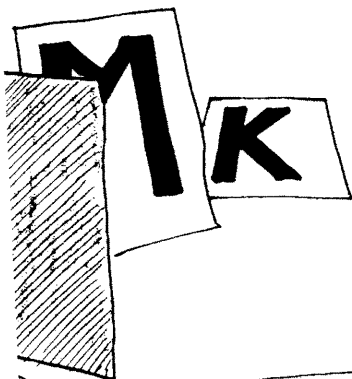
TURTLE-LY SHORTSIGHTED.



PATTERN RECOGNITION



THIS HIGH-RESOLUTION TV CAMERA WILL BE AN IMPROVEMENT ON THAT INFRARED EYE.



EACH SHAPE THAT COMES INTO THE CAMERA'S VIEW CAN BE THOUGHT OF AS A SET OF POINTS, OR TINY CELLS WITH COORDINATES X AND Y HORIZONTALLY AND VERTICALLY.

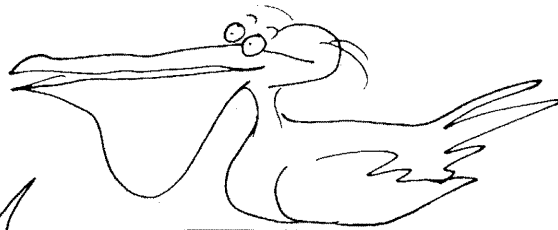
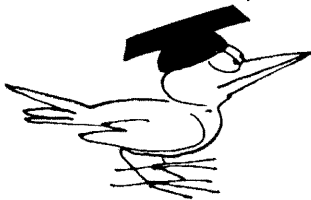
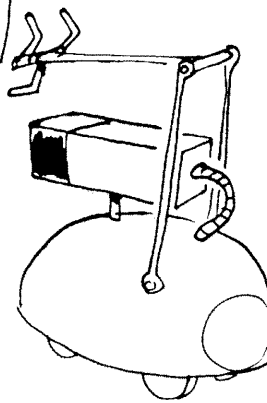
IN ORDER TO RECOGNIZE SOMETHING, YOU NEED TO HAVE SEEN IT BEFORE.

WE'LL HAVE TO START BY MAKING THE MACHINE MEMORIZE SOME BASIC FORMS.

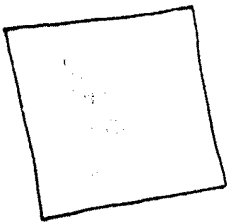


A B C D E F

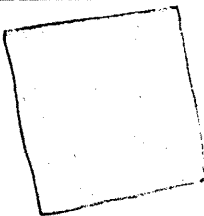
FOR INSTANCE, THE
LETTERS OF THE ALPHABET



YUR - I SEES WOTCHA MEAN. THEN YER SHOWS THE MACHINE
ANUVVER LETTER, H'AN IT COMPARES IT WIV THE ONES H'IT ORLREDDY
KNOWS.

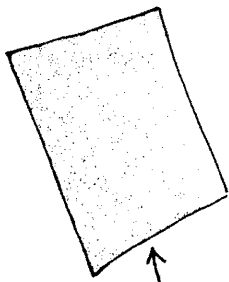


SIGNAL

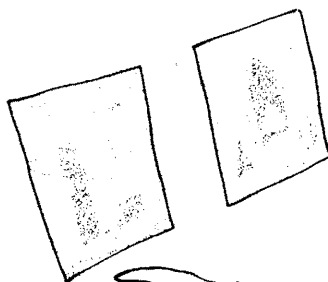


KNOWN SIGNAL

WHICH BOILS DOWN TO SUPERIMPOSING THE NEW
SIGNAL ON THE **NEGATIVE** OF THE ORIGINAL
ONE.

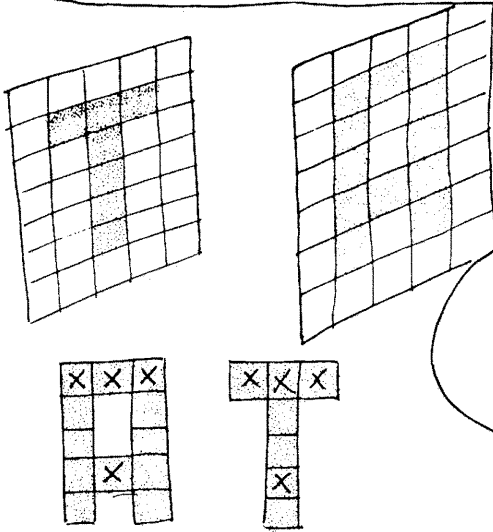


EXACT AGREEMENT



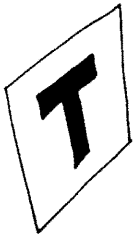
IF THE AGREEMENT
IS EXACT, THE RESULT
WILL BE UNIFORMLY
GREY.

TO BE PRECISE, THINK OF THE SIGNAL AS A SET OF VALUES (0 OR 1) ASSIGNED TO THE COORDINATE CELLS (X, Y). THE ON-BOARD COMPUTER CAN COUNT THE TOTAL NUMBER OF COINCIDENCES OR NON-COINCIDENCES.



COINCIDENCES: 4 CASES.
NUMBER OF CELLS IN SIGNAL: 7.
FRACTION OF COINCIDENCES: $4/7$.

YUR, BUT THERE'S A SNAG, MATE!
YER TURTLE CAN ONLY RECKERNIZE A LETTER
WOT'S H'EXACTLY LINED UP PROPER - AND
THE RIGHT DISTANCE AWAY.



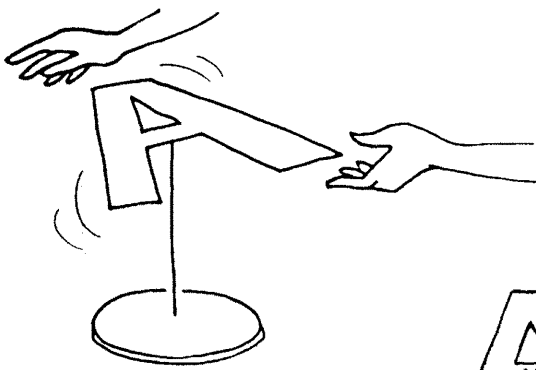
OH HECK!
THAT'S A TRICKY
ONE...



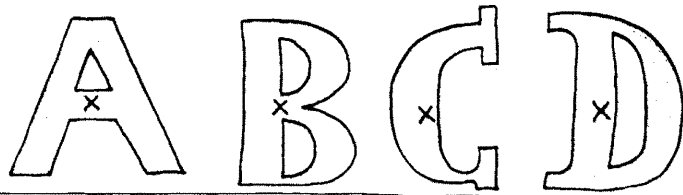
'AVE YER CALKYERLATED
'OW LIKELY THAT IS?

I THINK
I'VE GOT THE
ANSWER.

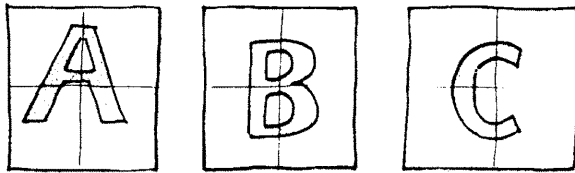




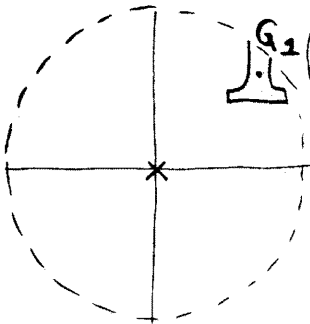
YOU WORK OUT THE CENTER OF GRAVITY OF EACH SYMBOL.



BEFORE RECORDING THE SYMBOL IN THE MACHINE'S MEMORY YOU ALIGN THE OPTICAL AXIS WITH THE CENTER OF GRAVITY.

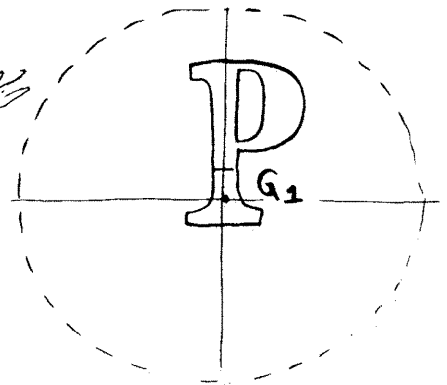
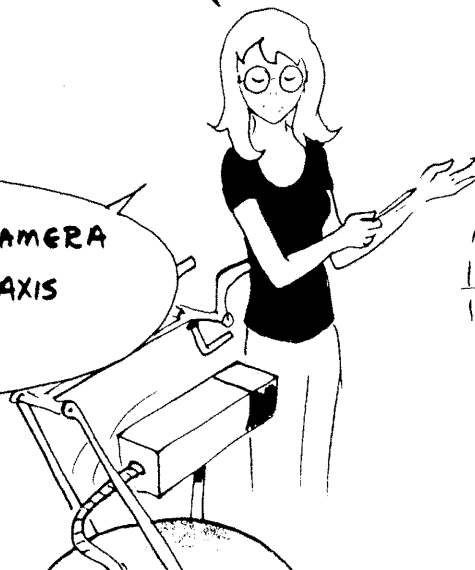


NOW, SUPPOSE SOME SHAPE ENTERS THE FIELD OF VISION.



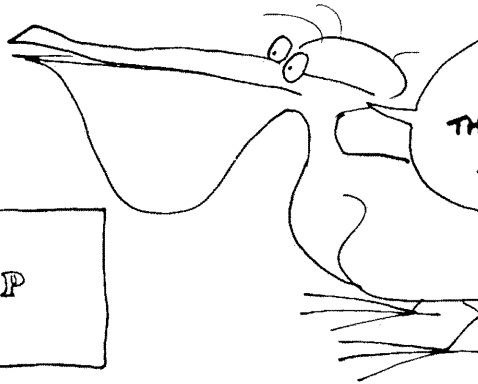
STRAIGHT AWAY, WE MAKE THE MACHINE COMPUTE THE CENTER OF GRAVITY G_1 OF THE PART THAT IT SEES.

THEN IT MOVES THE CAMERA TO ALIGN THE OPTICAL AXIS WITH G_1 .

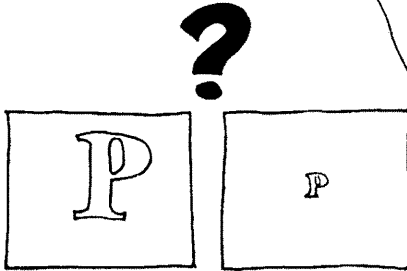


ONCE IT'S DONE THAT, THE MACHINE RECOMPUTES THE POSITION G_2 OF THE CENTER OF GRAVITY OF THE NEW IMAGE, AND RECENTERS ITSELF ON THAT...

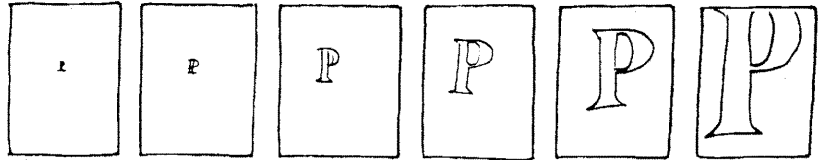
... WHICH LETS IT HOME IN PROGRESSIVELY ON THE OBJECT.



BUT WOT ABAHT THE PROBLEM OF FINDIN' THE RIGHT DISTANCE?

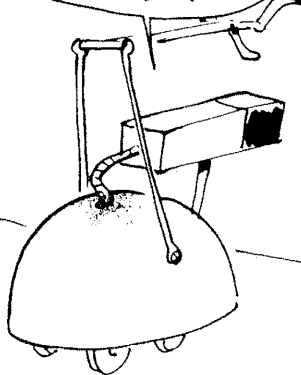


THE ON-BOARD COMPUTER CAN "DRAW N COPIES" OF THE IMAGE, ENLARGED OR REDUCED:



AND COMPARE EACH OF THESE WITH ITS REPERTOIRE OF STANDARD SYMBOLS HELD IN MEMORY.

GOSH! IT'S
A **P**!

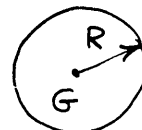
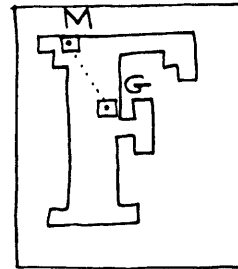
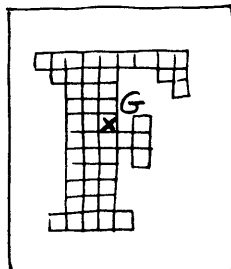


P



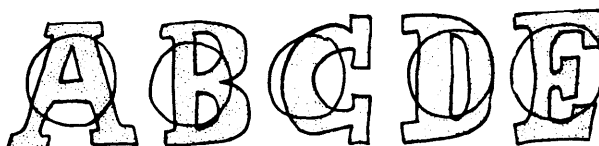
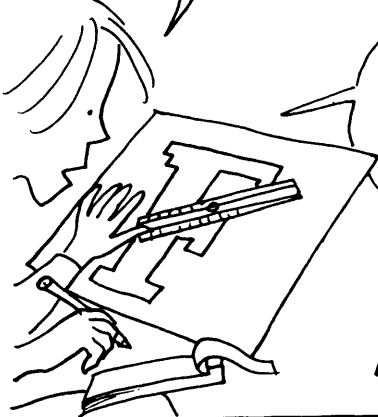
HANG ON— YOU DON'T NEED TO GO THROUGH ALL THIS MAGNIFICATION LARK. SEEN FROM A DISTANCE, A SHAPE IS JUST A SORT OF BLOB. ITS IMAGE NOT ONLY HAS A CENTER OF GRAVITY — IT ALSO HAS AN APPARENT DIAMETER.

HOW ARE YOU GOING TO WORK OUT THE DIAMETER?

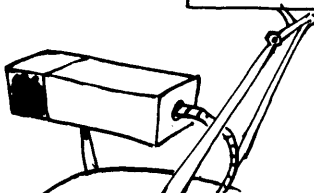
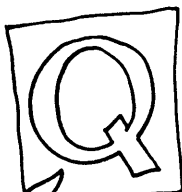
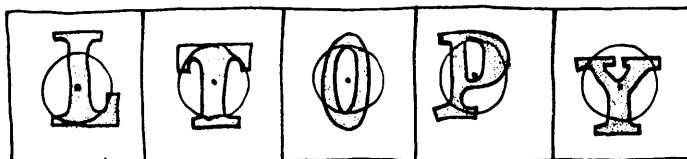


I LOOK AT ALL THE POINTS M THAT MAKE UP THE IMAGE, AND I JOIN EACH ONE TO THE CENTER OF GRAVITY G. I ADD UP ALL THE LENGTHS GM AND DIVIDE BY THE TOTAL NUMBER OF POINTS. I GET AN AVERAGE VALUE R, AND I SAY THAT $D = 2R$ IS A MEASURE OF THE APPARENT DIAMETER OF THE IMAGE.

EACH LETTER OR SYMBOL HAS A CIRCLE ATTACHED TO IT, CENTERED ON G, AND OF DIAMETER D.

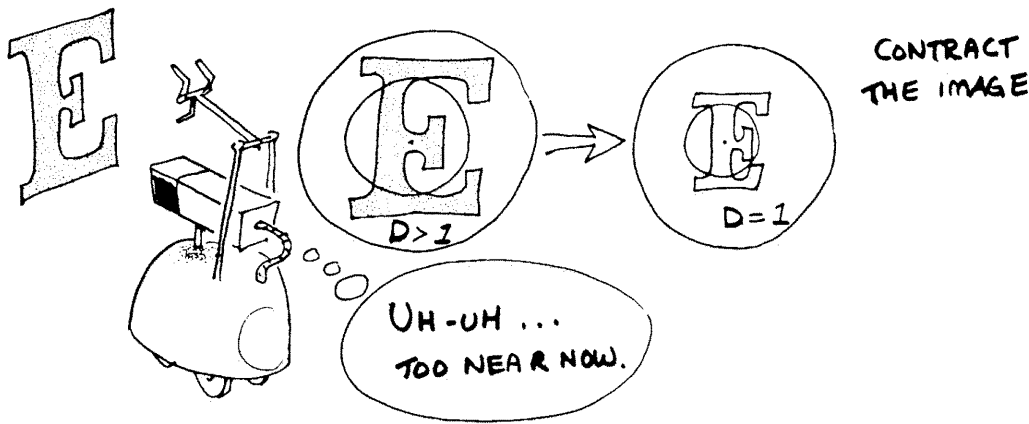
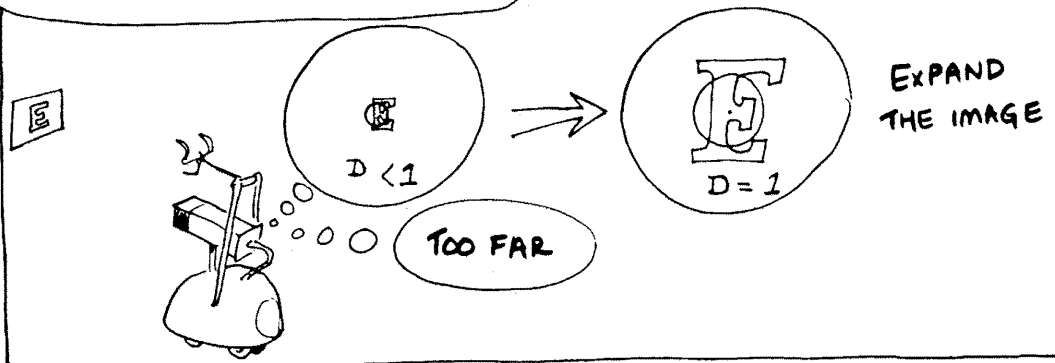


INSTEAD OF MEMORIZING THE SYMBOLS ANY OLD WAY, I ARRANGE FOR EACH TO HAVE THE SAME CENTER OF GRAVITY (SAY $x_G = 0, y_G = 0$) AND THE SAME APPARENT DIAMETER $D = 1$.

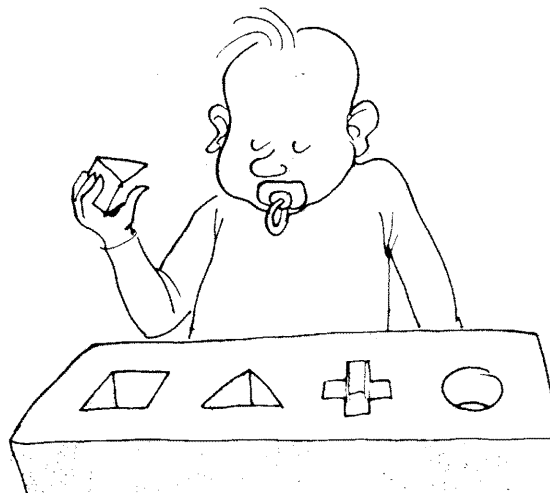


IN OTHER WORDS, YOU CENTER AND FOCUS THE SHAPE

WE'VE ALREADY SEEN HOW THE TURTLE CAN AUTOMATICALLY ALIGN ITS OPTICAL AXIS WITH THE CENTER OF GRAVITY. IT CAN ALSO COMPUTE THE APPARENT DIAMETER D OF THE IMAGE. IF THIS IS NOT EQUAL TO 1, THE CAMERA CAN ZOOM IN OR OUT UNTIL IT IS.



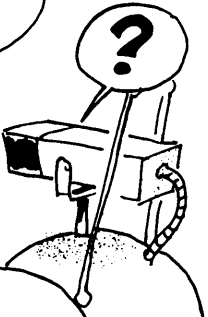
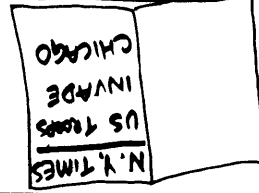
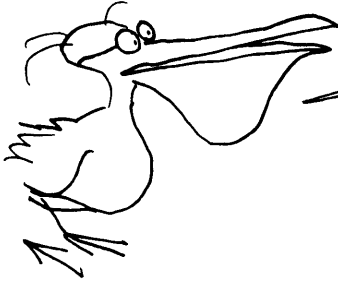
ALL IT HAS TO DO NOW IS RUN THROUGH THE SHAPES IN ITS MEMORY, TO SEE WHICH ONE FITS BEST.



BUT IT'S ALSO POSSIBLE FOR THE LETTER TO BE ROTATED. THEN YOU HAVE TO MAKE COPIES OF EACH IMAGE YOU WANT TO TEST, ROTATED FROM 0° TO 360° .



IF US YOONING BEIN'S DID IT THAT WAY, WE'D NEVER WORK AUT WOT WE WUZ LOOKIN' AT! IT'D TAKE DONKEY'S YEARS TER DECIDE!



WITH ONLY ONE MICROPROCESSOR — THAT IS, SMALL COMPUTER — YES. BUT WHAT WOULD YOU SAY TO A SYSTEM MADE UP OF THOUSANDS OF INDEPENDENT MICROPROCESSORS WORKING SIMULTANEOUSLY?



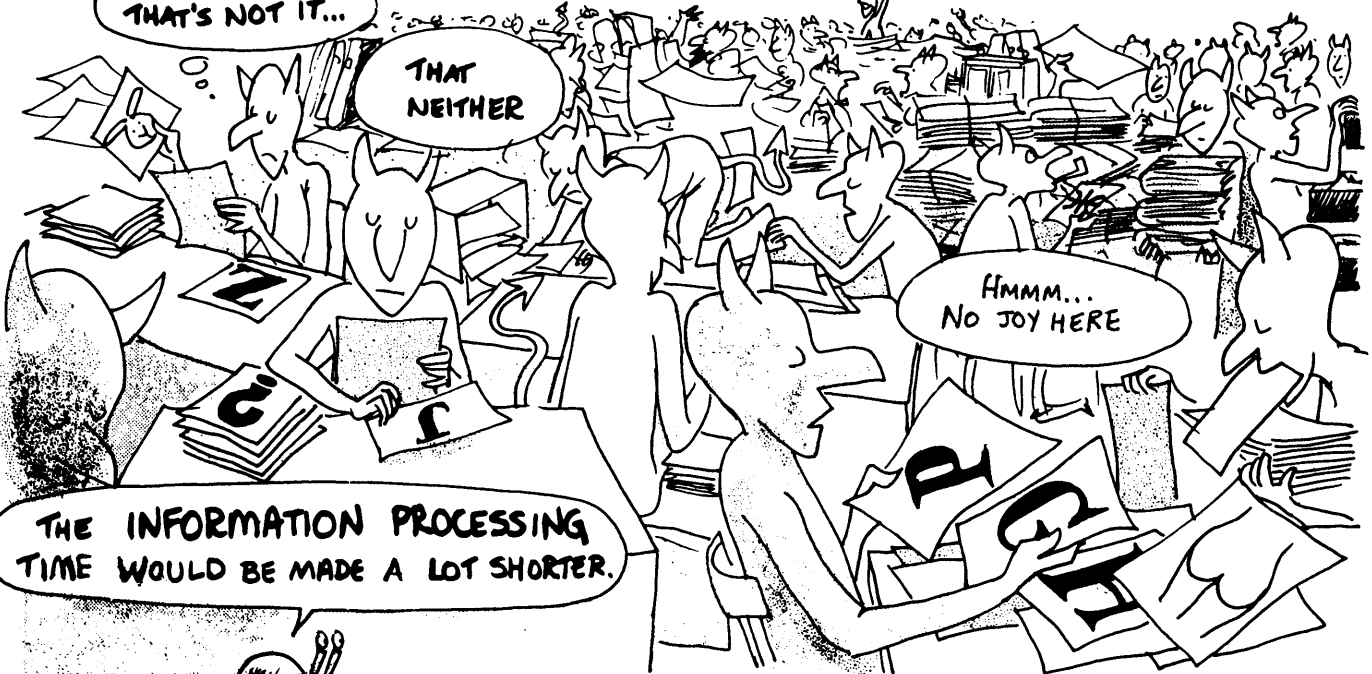
I'VE FOUND IT, EVERYONE!

NO, THAT'S NOT IT...

THAT NEITHER

HMMM... NO JOY HERE

THE INFORMATION PROCESSING TIME WOULD BE MADE A LOT SHORTER.



A LIVING CREATURE— A HUMAN BEING, SAY — HAS SPENT A LOT OF TIME LEARNING HOW TO RECOGNIZE FORMS. AS YOU READ THESE WORDS, YOUR BRAIN, PROCESSING INFORMATION RECEIVED BY YOUR EYES, IS AS POWERFUL AS 10,000 MICROPROCESSORS WORKING SIMULTANEOUSLY IN PARALLEL.

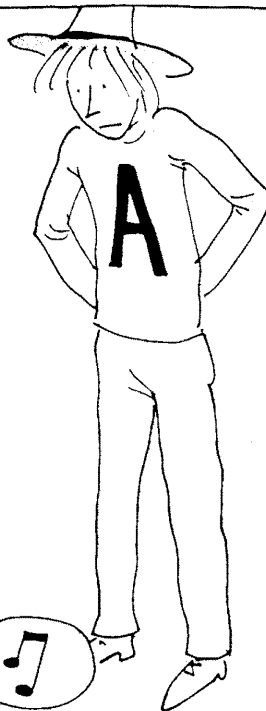


WHICH BOGGLES
MY MIND

BASICALLY, IT'S AMAZING
THAT WE THINK OF OURSELVES AS
A SINGLE CREATURE AT ALL.



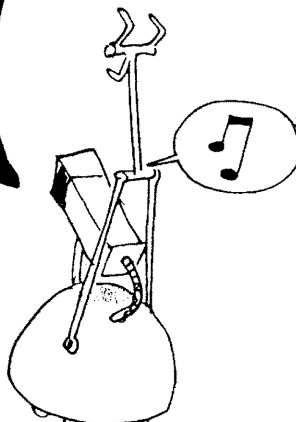
ACTUALLY, PATTERN RECOGNITION IS AN EXTREMELY COMPLICATED PROBLEM.
WHAT WE'VE SHOWN YOU IS JUST A ROUGH OUTLINE.



A TURTLE WOT CAN
READ.

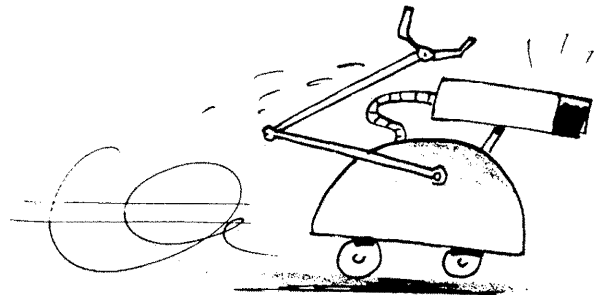
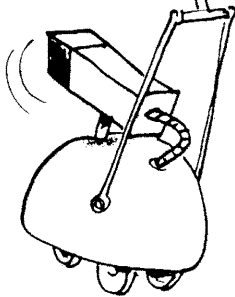


NOW I'VE
SEEN IT ORL.

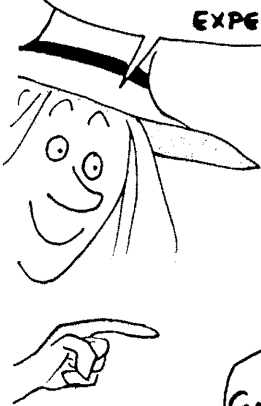


IF THE TURTLE CAN READ LETTERS, IT CAN ALSO PUT THEM TOGETHER TO RECOGNIZE WORDS, OR SENTENCES.

DANGER

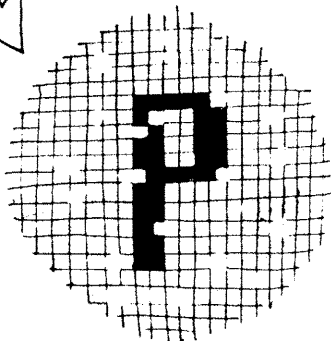


NOW THIS IS AN INTERESTING EXPERIMENT.



GOSH, IT'S SNOWING!

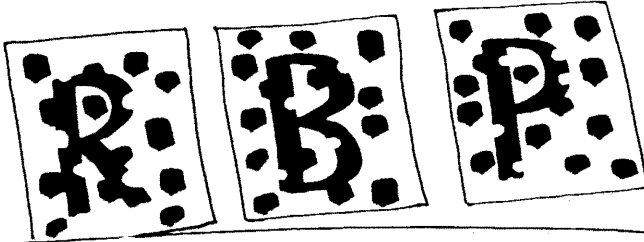
HERE'S THE LETTER THE WAY THE TURTLE SEES IT AT A GIVEN MOMENT.



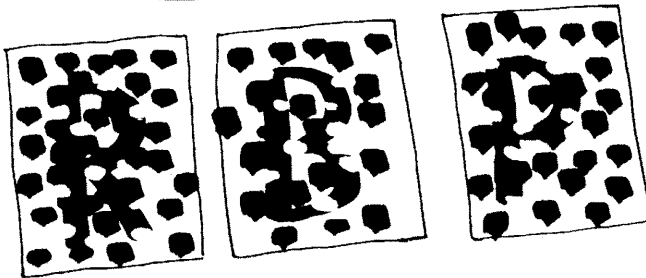
NOISE

EACH IMAGE IS DISTORTED BY BACKGROUND NOISE.

HERE'S ONE IDEA: 100% AGREEMENT ISN'T REALLY NECESSARY TO BE ABLE TO RECOGNIZE A SIGNAL.



NOISE NOTWITHSTANDING, THESE SIGNALS ARE PERFECTLY CLEAR, AND DISTINGUISHABLE.



THE AGREEMENT IS NO MORE THAN 75%

I CAN'T RECOGNIZE A THING NOW!

BUT... SUPPOSE YOU TAKE SEVERAL IMAGES OF THE SAME NOISY OBJECT.

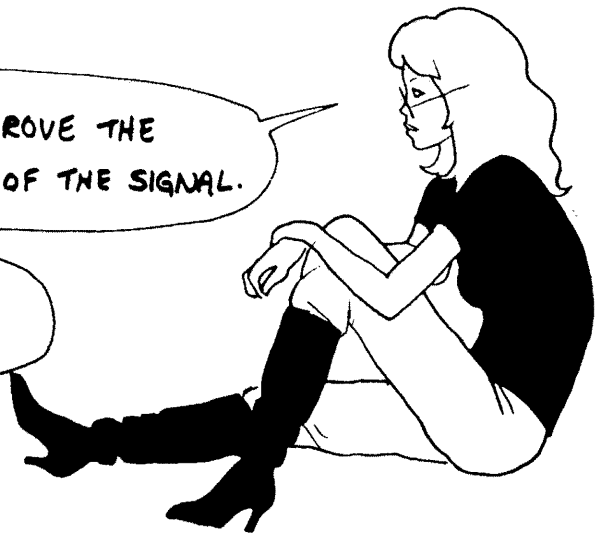


I MIGHT POINT OUT THAT SINCE WE HAVE TWO EYES, WE ALWAYS WORK WITH TWO IMAGES ANYWAY

IMAGE PROCESSING

By combining N images, you can improve the level of perception, the detection of the signal.

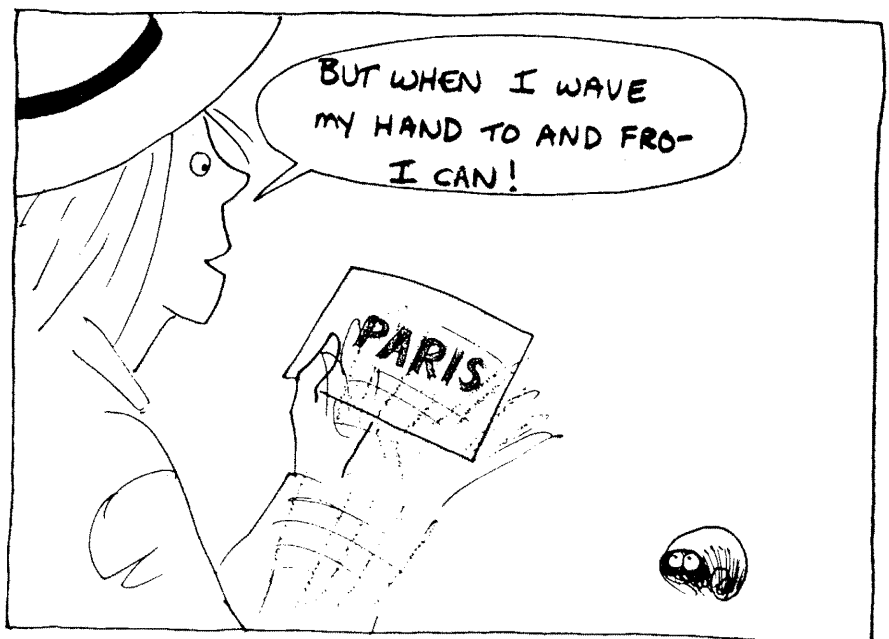
For instance, you can superimpose them (or take an average).



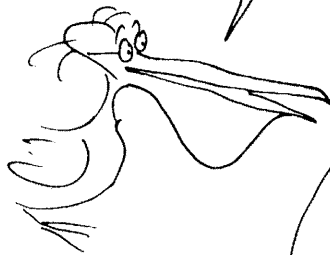
There are also more sophisticated mathematical techniques.

When I hide the signal with my hand, I can't read it.

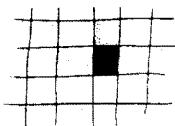
But when I wave my hand to and fro - I can!



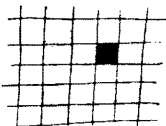
LESSEE IF I GOT YER DRIFT RIGHT. YER WANNA BE ABLE TER RECKERNIZE SIGNALS NO MATTER WOT'S 'APPENIN' — SNOW, 'AIL, 'URRICANES AN' WOTNOT. NAR THAT MEANS YER NEED TER COMPUTE ORL THIS MONKEY-BUSINESS WIV CENTERS O' DEPRIVITY AN' H'APPARENT DYNAMOMETERS 'OW D'YER PLAN TO DO THAT WIV ORL THIS BACKGROUND NOISE?



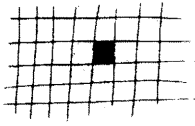
I THINK I'VE GOT AN IDEA. WE "CLEAN UP" THE IMAGE. SUPPOSE WE LOOK AT EACH POINT IN TURN AND ELIMINATE ALL THOSE THAT HAVE FEWER THAN TWO NEIGHBORS?



TO STAY



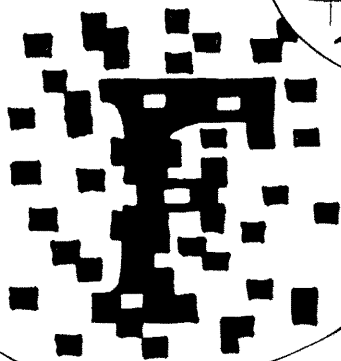
TO DIE



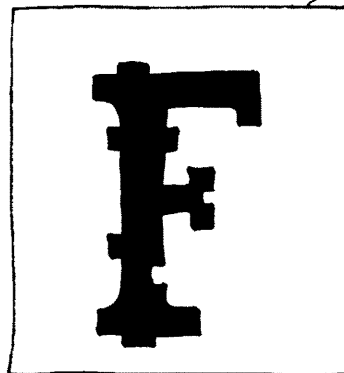
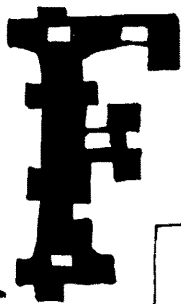
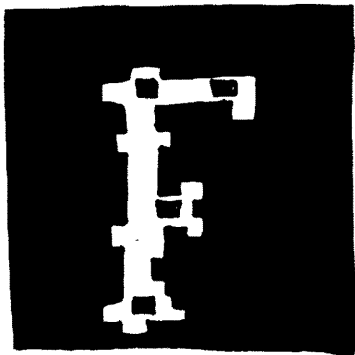
TO STAY



THAT WILL GET RID OF MOST OF THE ISOLATED BLOTCHES.



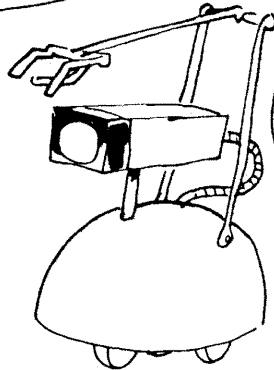
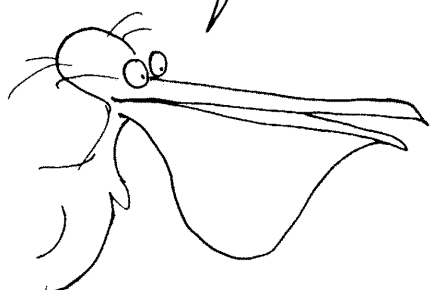
THEN YOU "INVERT" THE IMAGE AND DO IT AGAIN.



HERE'S WHAT YOU GET AFTER THE SECOND CLEANING OPERATION.



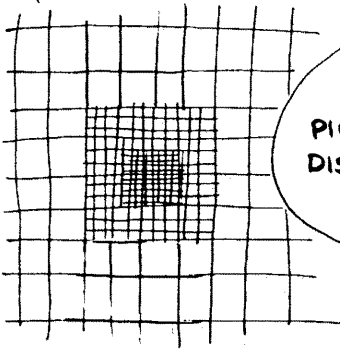
HOKAY, YER TURTLE CAN
READ IN THE SNOW.
SO WOT?



LENNY: PRETEND
THAT THE TURTLE'S EYE
IS AS GOOD AS A HUMAN'S.



THE NUMBER OF
PICTURE CELLS THAT CAN BE
DISTINGUISHED IS GREATEST
NEAR THE MIDDLE.



To read a message,

AROUND THE SYMBOLS ERRATICALLY.

THE EYE'S OPTICAL AXIS JUMPS

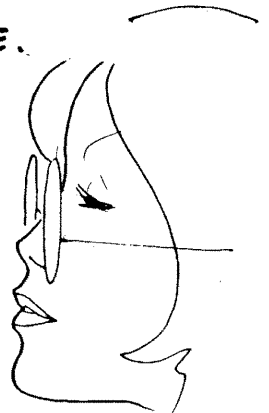
Or none meaning

To read a message

ONLY A FEW REGIONS ARE PERCEIVED
WITH ANY CLARITY.

BUT THE BRAIN RECONSTRUCTS THE MOST LIKELY MESSAGE.

WHICH LETS US READ
VERY RAPIDLY.



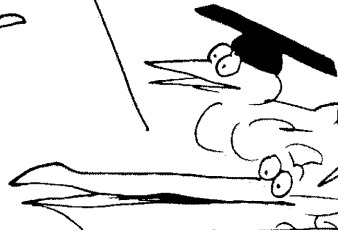
IT'S REASONABLE ENOUGH. TO GATHER **ALL** THE INFORMATION, READ THE MESSAGE WORD BY WORD, THE WORDS LETTER BY LETTER, THE LETTERS STROKE BY STROKE - YOU'D NEVER GET STARTED!



CERTAIN KEY FORMS LET US IDENTIFY LETTERS.



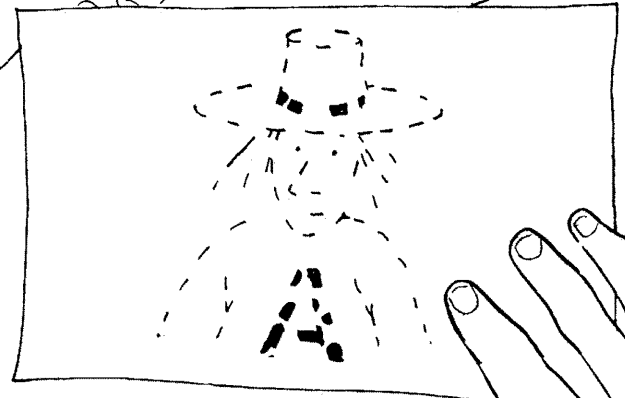
LOOKS LIKE THERE'S MORE H'INFORMATION THAN YER REALLY NEED.



TWO GLANCES AT THE START AND FINISH OF A WORD ARE USUALLY ENOUGH.



AND WHAT GOES FOR READING IS ALSO TRUE OF OTHER TYPES OF PERCEPTION.



IF YOU GET THE IMPRESSION SOMETHING'S NOT QUITE RIGHT, THE EYE TAKES ANOTHER QUICK GLANCE AT THE PROBLEM AREA.



PERCEPTION

WE **THINK** WE'RE RECEIVING INFORMATION ALL THE TIME.



BUT ALL WE ACTUALLY TAKE FROM OUR SURROUNDINGS IS THE **MINIMUM** OF INFORMATION NEEDED TO IDENTIFY SHAPES, SOUNDS, AND SO FORTH.



ALL THE TIME, THESE IMPRESSIONS ARE COMPARED TO AN ENORMOUS BANK OF SIGNALS AND SYMBOLS IN OUR MEMORIES...

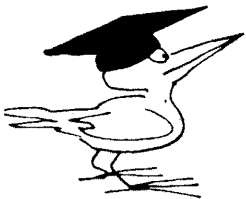
*A memory
written in the
sand*

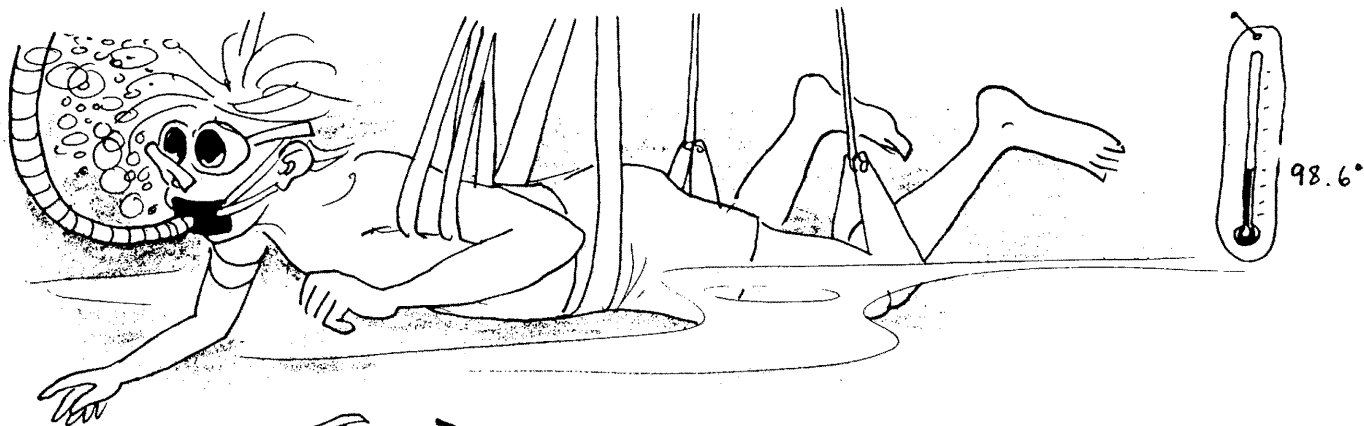


...WHICH ARE CONSTANTLY **REFRESHED**



IT'S BEEN DISCOVERED THAT IF YOU CUT SOMEONE OFF FROM ALL OUTSIDE SENSATIONS, THE MIND QUICKLY STARTS TO DRIFT...





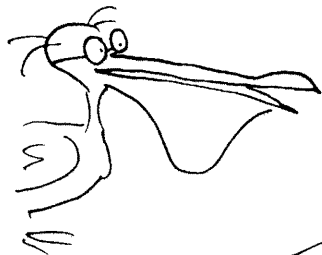
AFTER A FEW DAYS OF SUCH **SENSORY DEPRIVATION** ONE CAN HARDLY
MANAGE EVEN VERY SIMPLE ACTIONS, LIKE PICKING UP A GLASS. IT'S AS
IF THE IDEA THAT WE ARE PART OF THE OUTSIDE WORLD NEEDS TO BE
CONSTANTLY RENEWED.

WE'RE IN A
CONSTANT STATE
OF LEARNING.

SO, WOT ABAHT THE TURTLE? H'IT CAN
RECKERNIZE ALL SORTS O' FINGS QUICK AS A BLINKIN' FLASH,
COME RAIN, SLEET OR SNOW; H'UPSIDE DAHN OR
H'INSIDE AUT. **SO WOT?**

H'IT'S STILL COMPLETELY **STUPID**

THE ONLY THINGS IT CAN DO ARE WHAT YOU PUT INTO ITS SILLY 'HEAD



ENTER

STOP

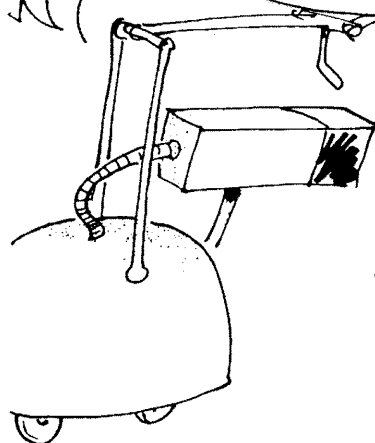
EXIT

GET STUFFED

LOOK OUT!



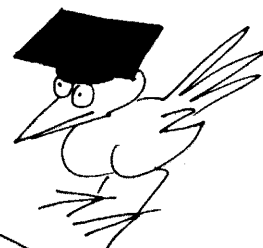
YOU COULD TRY ADDING A RANDOMIZING DEVICE TO GIVE THE TURTLE'S BEHAVIOR A BIT OF VARIETY.



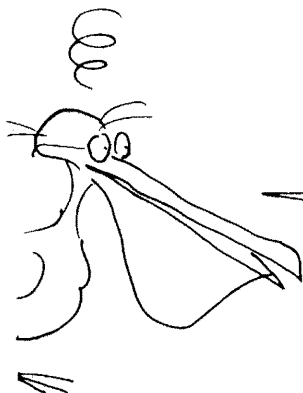
AS IF IT TOSSED A COIN OCCASIONALLY TO DECIDE WHAT TO DO.



LIVING CREATURES DON'T BEHAVE IN A 100% REGULAR WAY.



I MUST H'ADMIT I SOMETIMES TAKES IT INTER ME 'HEAD TO DO... WELL, ORL SORTS O' THINGS!



INTELLIGENCE AND STUPIDITY

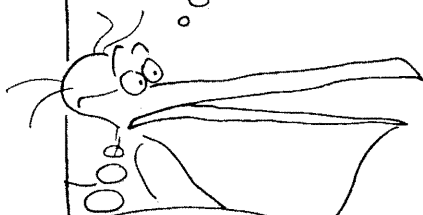


BUT ORL THAT'S JUST CREATIN' A
H'ILLUSION OF H'INTELLIGENCE! THE DUMB
MACHINE'S STILL TOTALLY STUPID!

LENNY: WHAT
IS INTELLIGENCE?



INTELLIGENCE IS...
CRIPES! A DEFFYNITION,
QUICK!



I DO FEEL
A FOOL.

WE OFTEN ACT JUST
LIKE AUTOMATONS - AS IF
WE WERE CONDITIONED
OR PROGRAMMED.



"A MAN WHO IS CAPABLE OF MARCHING IN STEP
TO MUSIC DOESN'T NEED A BRAIN. A SPINAL CORD
IS QUITE SUFFICIENT." (*)



INTELLIGENCE IS SOMETHING THAT FLOATS ON TOP OF A SEA OF
CONDITIONED RESPONSES AND PRECONCEIVED IDEAS.

WHAT YOU'VE BEEN DOING
SO FAR IS ATTEMPTING TO
REPRODUCE THE BEHAVIOR OF
ANIMALS HIGHER AND HIGHER UP
THE EVOLUTIONARY LADDER.

SNIF!...

SSSSS

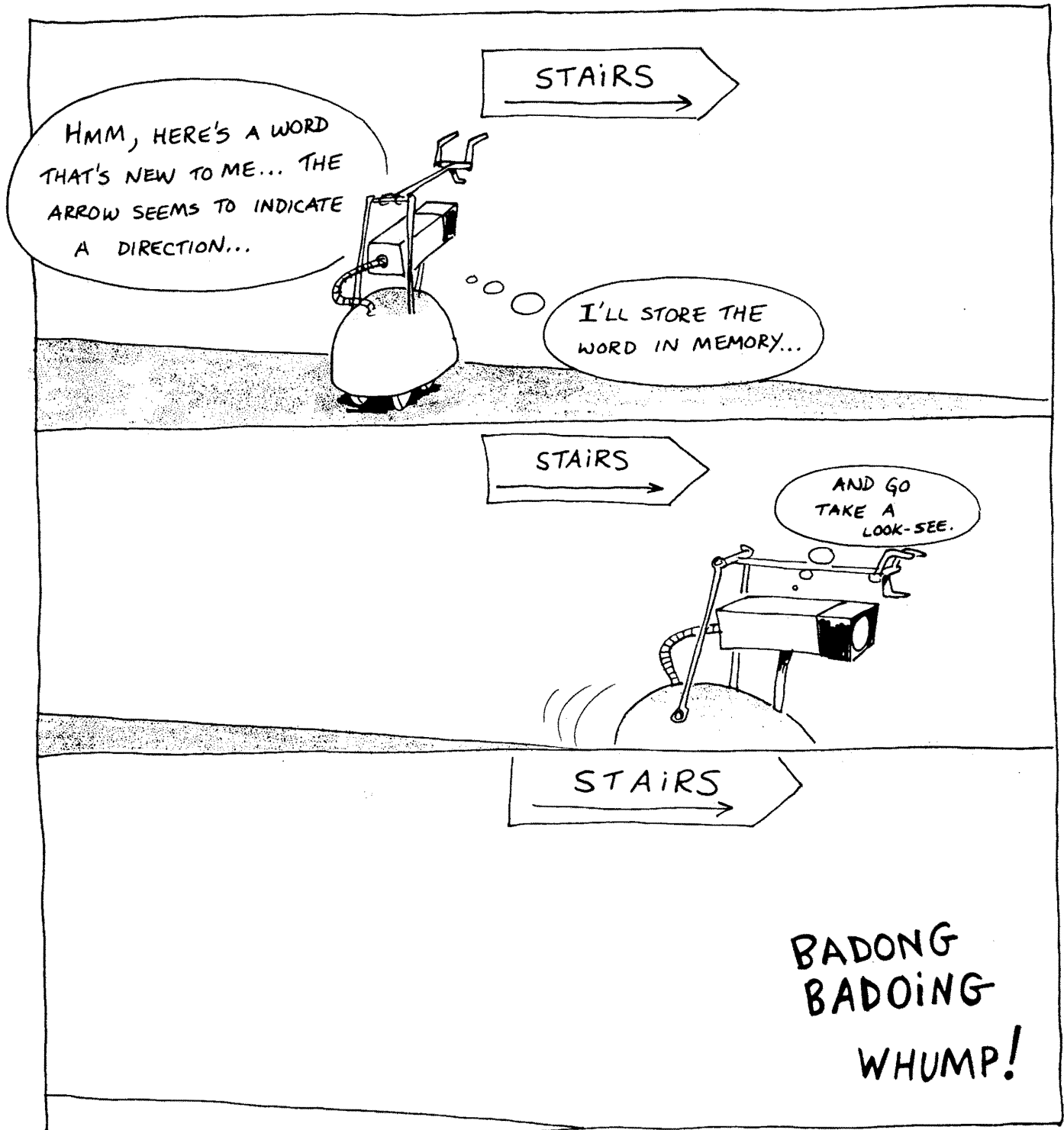
!!!

EVEN IF NO HUMAN BEING IS BORN FULLY EQUIPPED
WITH LANGUAGE OR IDEAS, EACH STARTS OUT WITH
A CERTAIN AMOUNT OF INNATE ABILITY, A STOCK OF
PROGRAMMED RESPONSES OR INSTINCTS. THESE
ARE IMPRINTED ON THE MIND AT THE TIME OF
CONCEPTION, DURING THE FETAL STAGE,
AND IN THE EARLY STAGES OF LIFE.

AND THAT TRANSLATES
IN PARTICULAR INTO A
TENDENCY TO EXPLORE AND
TO LEARN.

I'M GOING TO TEACH MY
TURTLE TO LEARN.

TRIAL-AND-ERROR STRATEGY



EXCELLENT. MOREOVER,
I'M NOT SURE I LIKE
STAIRS VERY MUCH.

CRRRRii....

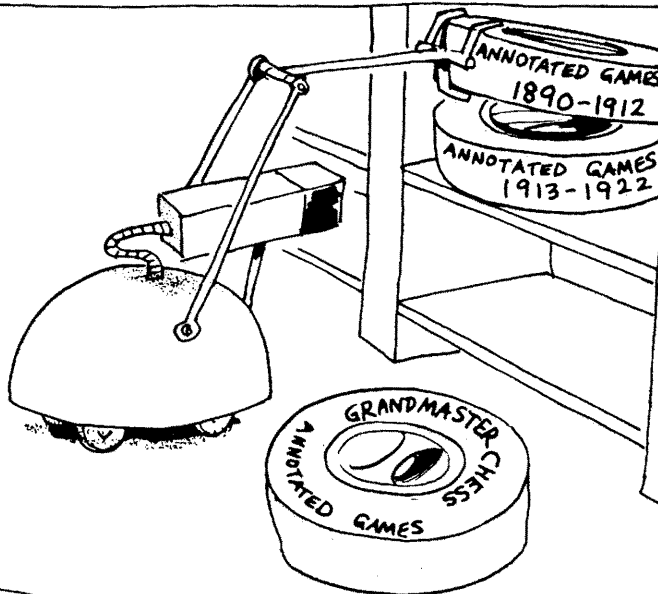
CRRRRriiii...

THE TURTLE CAN SUFFER EXPERIENCES AND PROFIT FROM THEM BY
DRAWING APPROPRIATE CONCLUSIONS.

... AT SIXTY
VOLTS I CHARGE
UP FAST, BUT IT'S
AWFUL HOT!

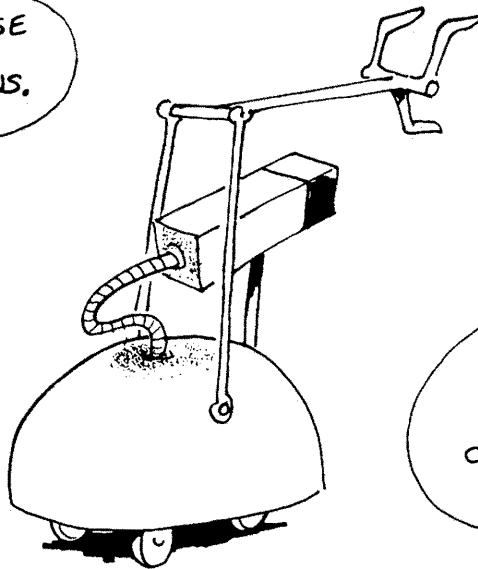
THE TRICK IS TO
KNOW JUST HOW FAR YOU
CAN AFFORD TO GO WITH
THIS SORT OF LEARNING.

A MACHINE CAN GATHER ALL SORTS OF DATA.



FOR A START,
IT HAS ACCESS TO
OUTSIDE
DATA BANKS.

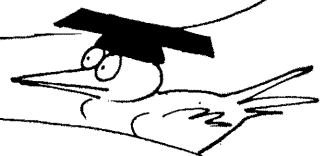
AND IT CAN ALSO USE
ITS OWN SENSE ORGANS.

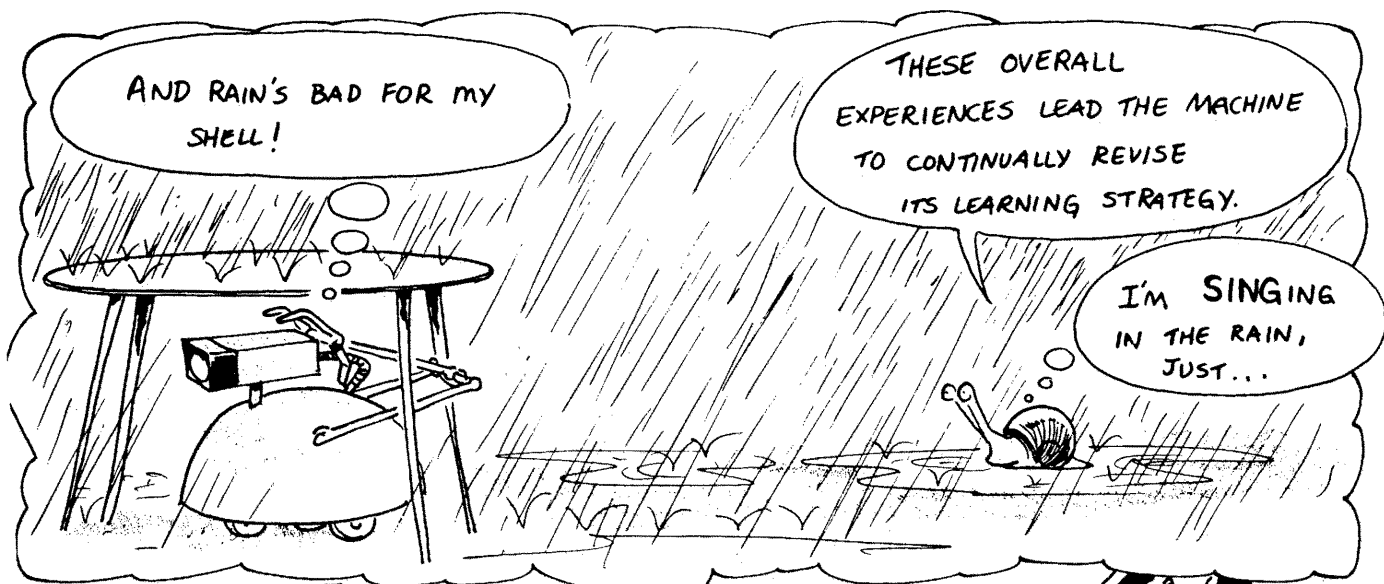


IT CAN ANALYZE THE
DATA, AND SEARCH FOR
CORRELATIONS BETWEEN EVENTS.

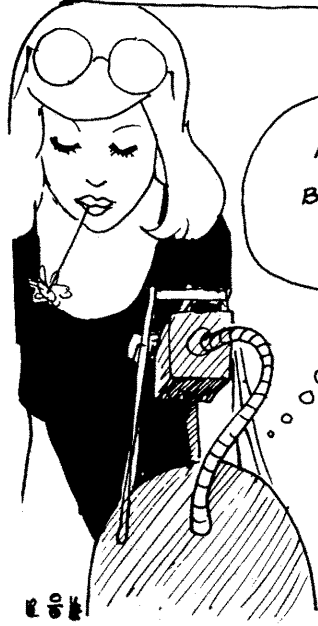


I'VE NOTICED THAT WHENEVER
THESE FUNNY GREY THINGS START TO PILE UP,
IT'S NOT LONG BEFORE IT STARTS
TO RAIN.





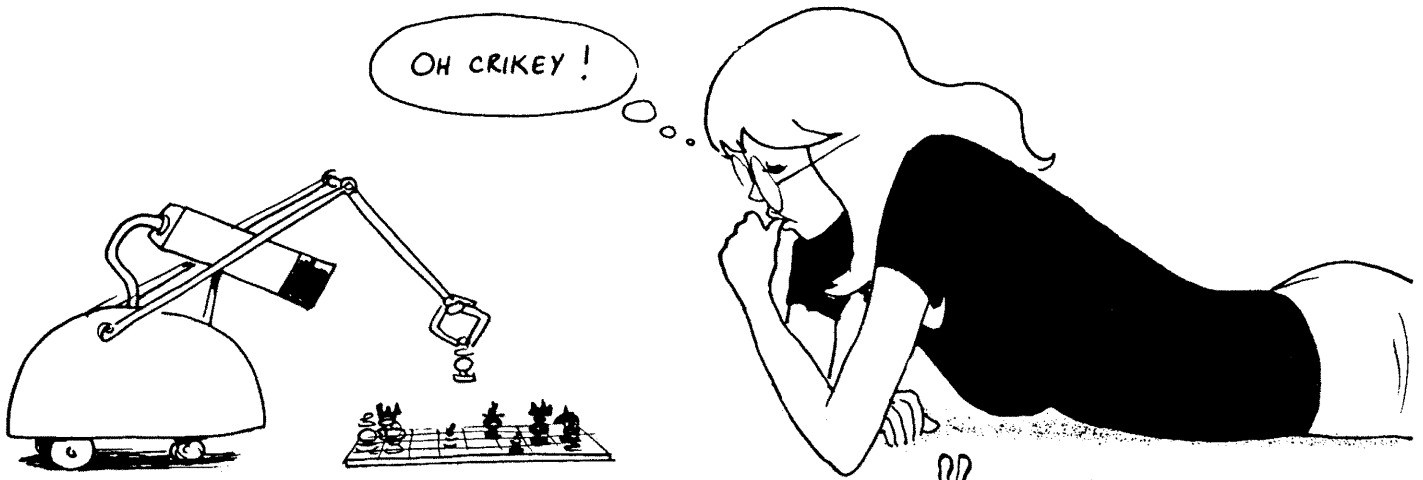
NOW, THE LAST TIME THIS POSITION OCCURRED, IT TURNED OUT NOT TO BE A GOOD IDEA TO MOVE THE ROOK.



APART FROM THAT PAWN, THE POSITION LOOKS LIKE THE GAME BETWEEN ALEKHINE AND MORPHY IN 1924. BUT A PAWN CAN'T MAKE MUCH DIFFERENCE...

I'LL TRY MOVING THE BISHOP.

WE'LL SOON SEE...



SO WHERE DOES INTELLIGENCE START
AND STUPIDITY LEAVE OFF?

THE TURING TEST

DON'T FORGET THAT SINCE
1981 THE WORLD
BACKGAMMON CHAMPION HAS
BEEN A COMPUTER.

A MATHEMATICIAN ONCE PROPOSED THE FOLLOWING TEST FOR INTELLIGENCE:



HELLO, MISS - CAN
YOU TELL ME IF THERE'S
A VACANT SEAT ON THE
TRAIN AT 10:30
THIS EVENING?

YES, SIR, THERE IS.
SHALL I RESERVE A
SLEEPING COMPARTMENT?

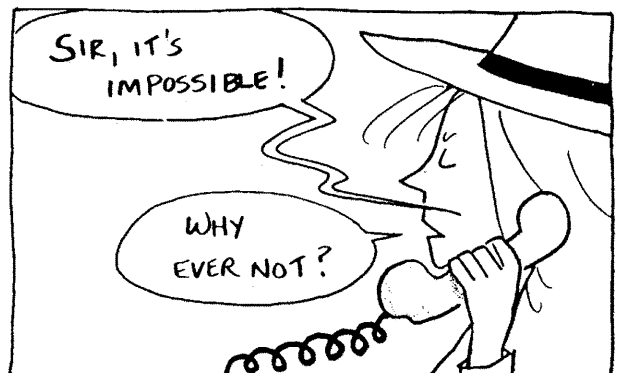


YOU KNOW, YOU HAVE A CHARMING
VOICE.



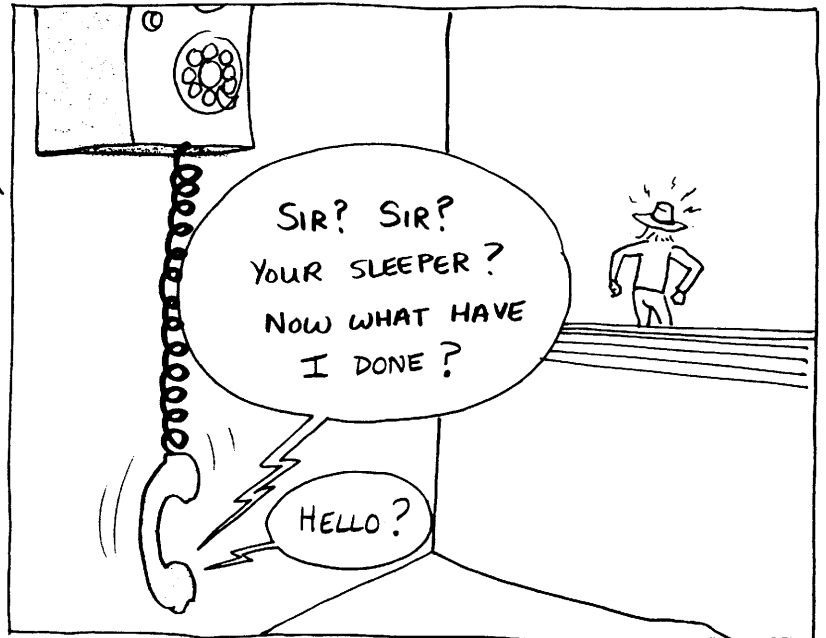
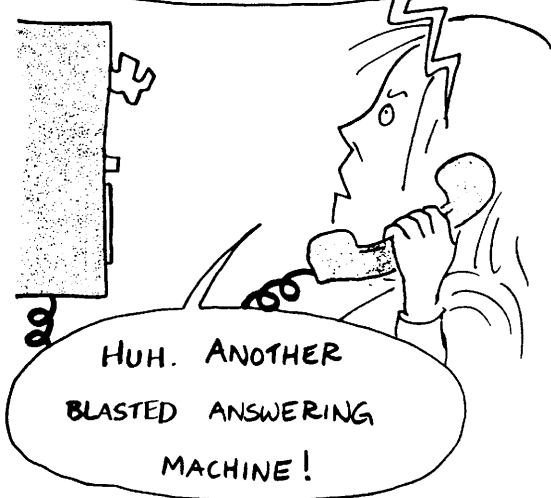
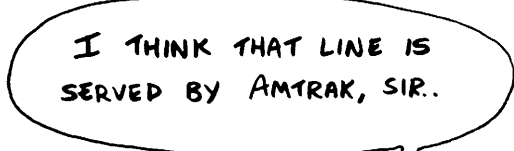
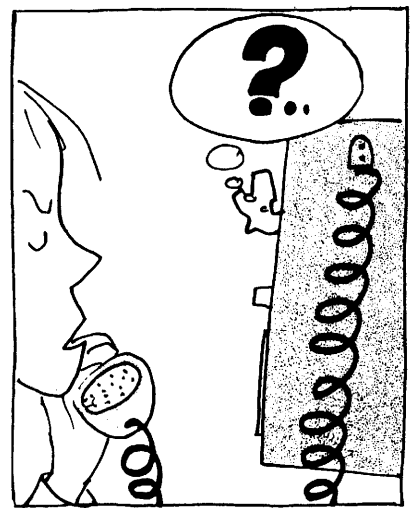
OH SIR, YOU ARE
A ONE!

YOU AREN'T BY
ANY CHANCE FREE SOME
EVENING THIS WEEK?



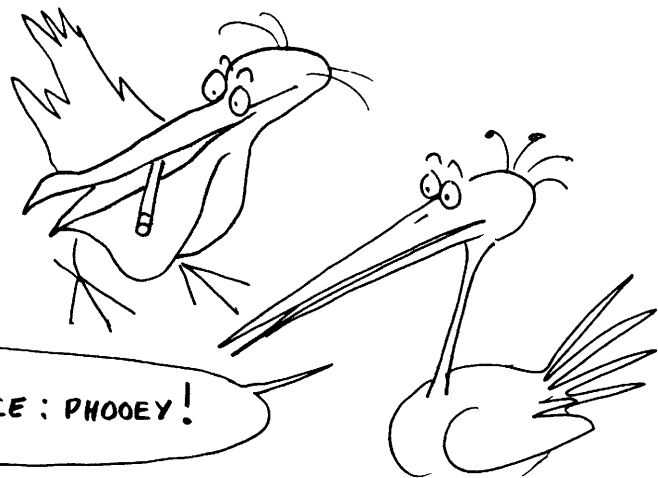
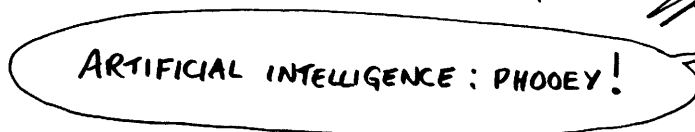
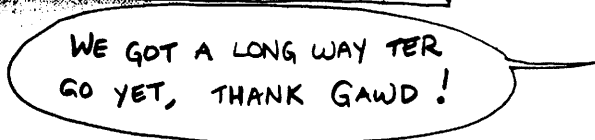
SIR, IT'S
IMPOSSIBLE!

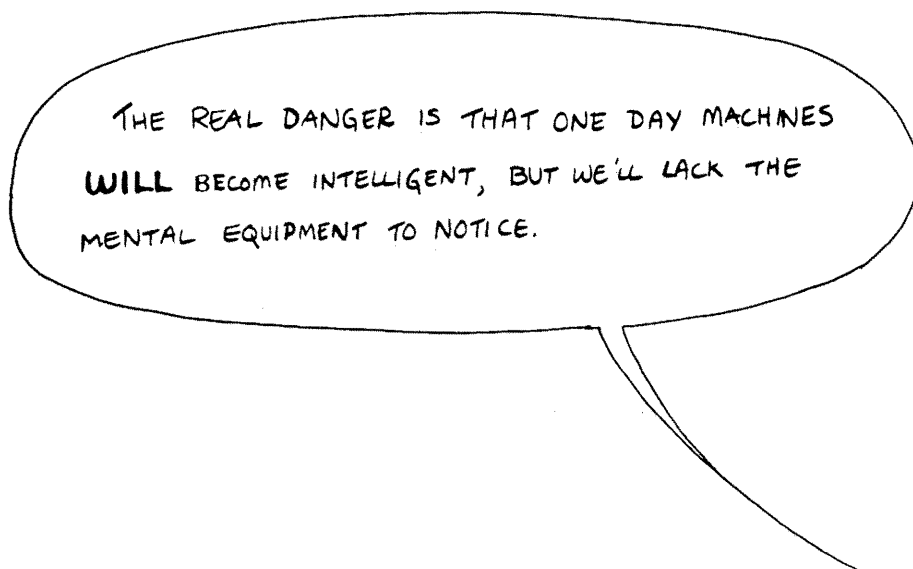
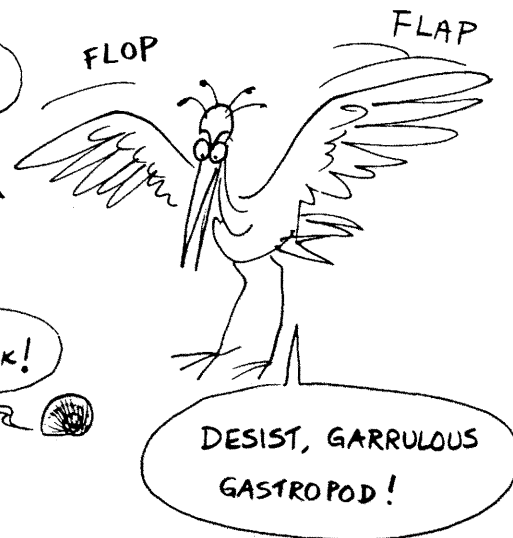
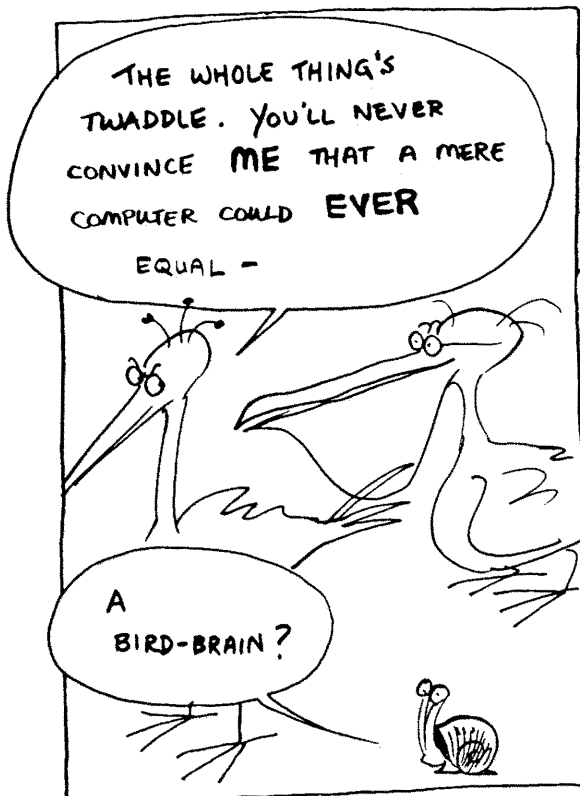
WHY
EVER NOT?



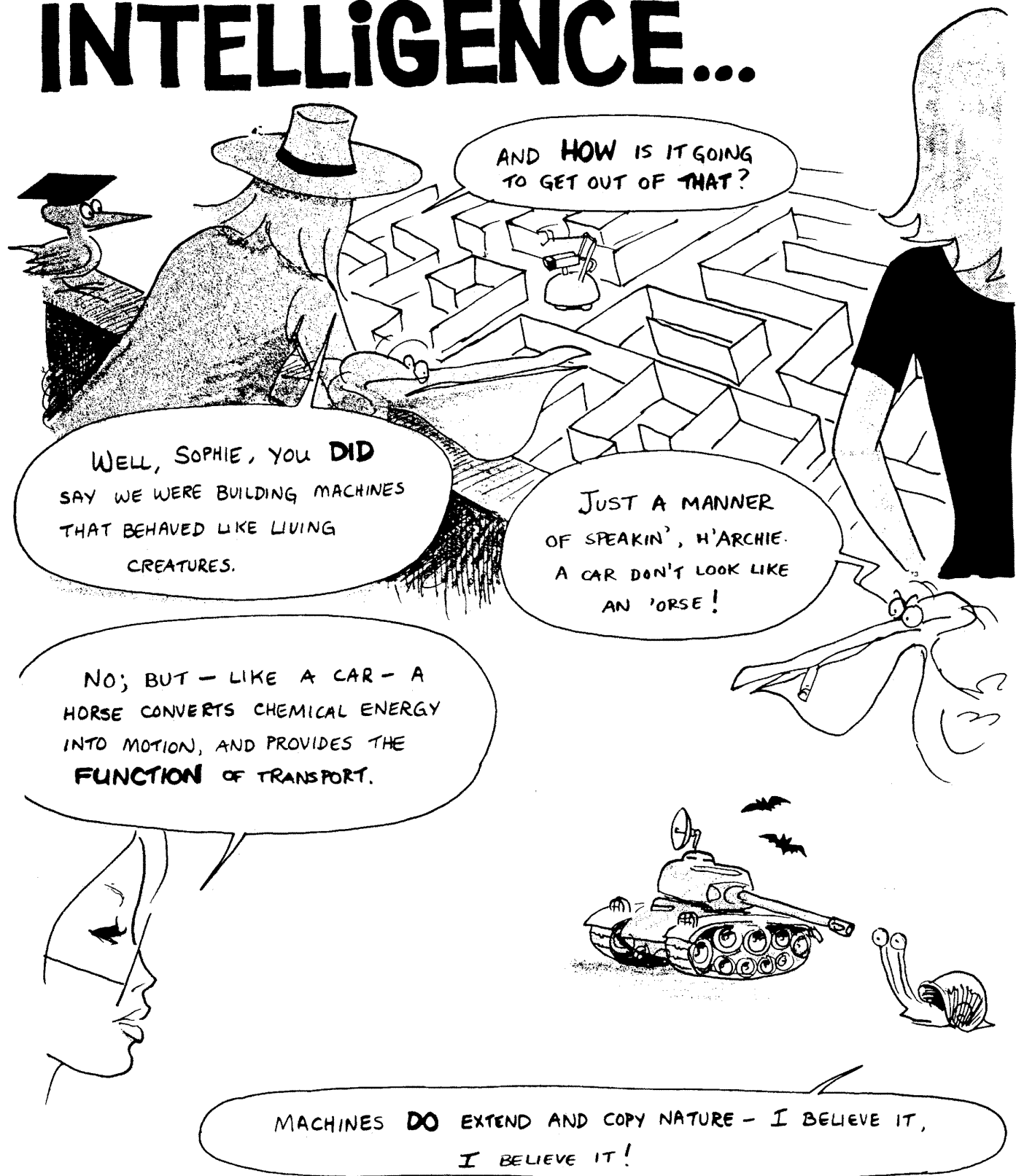
A MACHINE WILL BE CONSIDERED INTELLIGENT IF ITS RESPONSES CANNOT BE DISTINGUISHED FROM THOSE OF A HUMAN BEING

Turing





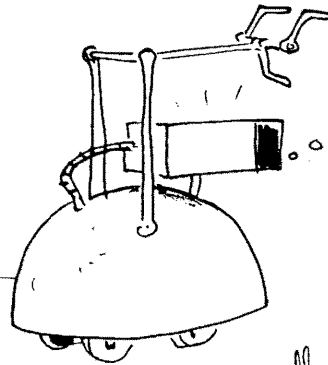
ARTiFiCiAL INTELLiGENCE...



WITH **CYBERNETICS** AND **INFORMATION SCIENCE** WE'VE IMITATED THE **CONTROL** AND **PROGRAMMING** FUNCTIONS OF LIVING CREATURES. THE **INSTINCTIVE** SIDE.



I'LL BEAT IT ALL RIGHT!



BEAT IT!

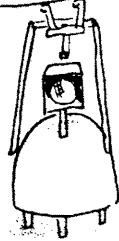
THE INSTINCT OF SELF-PRESERVATION.

DON' STOP NOW - THIS IS GETTIN' FASCINATIN'.

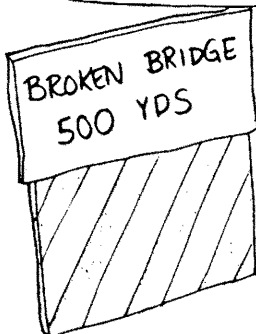


WE'VE ALREADY BEEN ABLE TO GIVE MACHINES THESE POWERS:

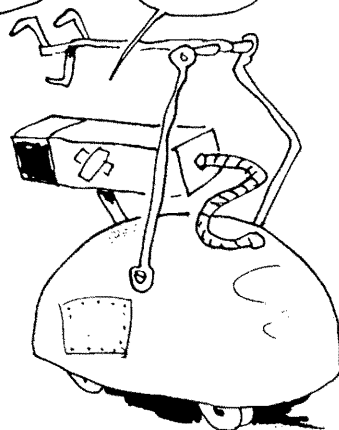
IT'S COLD - I'LL WARM UP MY CIRCUITS.



THE POWER OF LEARNING

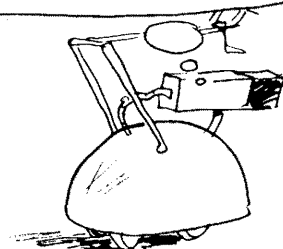


?

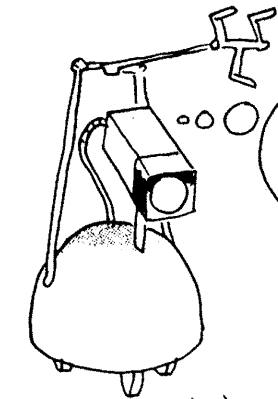


THE POWER OF DEDUCTION

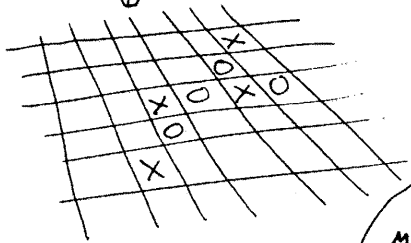
NOW, ALL GREEKS ARE LIARS;
AND EPIMENIDES IS A GREEK;
SO...



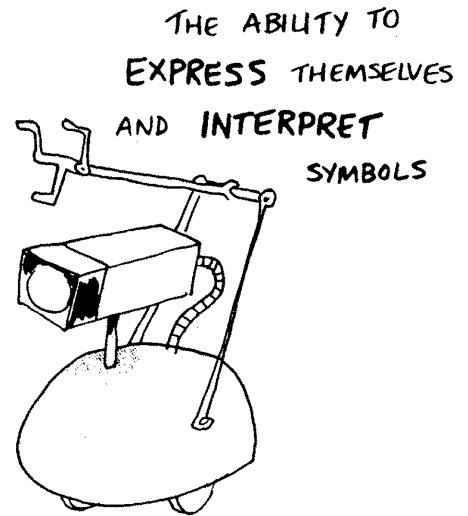
THE POWERS OF DISOBEDIENCE, IMAGINATION, AND RECOGNITION OF THE OUTSIDE WORLD



LET'S SEE : IF I
DISOBEY MY PROGRAMMING
AND TRY THIS...



THIS WOULD SEEM TO
MODIFY THE RELATION
BETWEEN THE MEDIUM
AND THE MESSAGE...

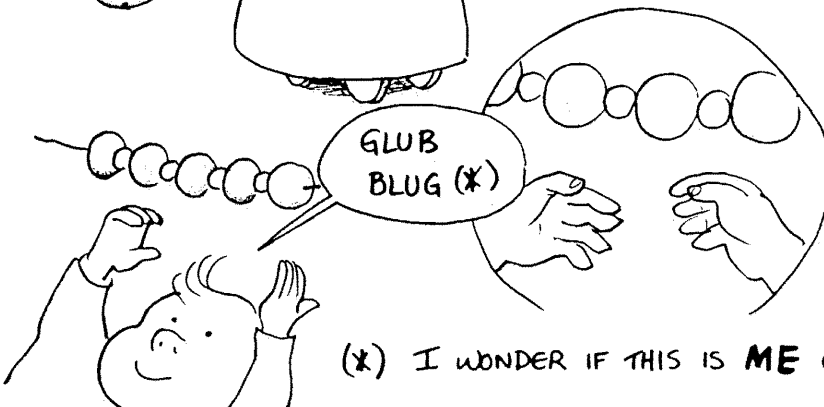


THE ABILITY TO
EXPRESS THEMSELVES
AND INTERPRET
SYMBOLS

AMONG THE SIGNS AND IMAGES PERCEIVED, SOME ARE RELATED TO THE
OUTSIDE WORLD, OR **NON-SELF**; AND OTHERS TO THE **SELF**, THE ACTUAL MACHINE.
THE ACQUISITION OF **SELF-AWARENESS** IS THE BEGINNING OF A **CONSCIOUSNESS**
OF EXISTENCE.

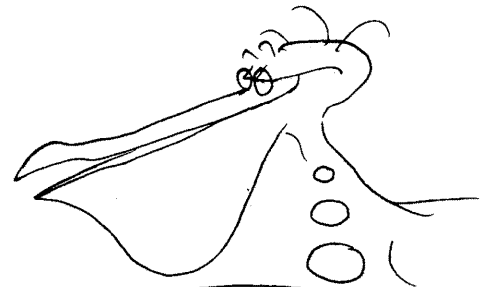


I WONDER IF THIS IS
ME OR **NON-ME**?



GLUB
BLUG (*)

(*) I WONDER IF THIS IS **ME** OR **NON-ME**?



WOOLGATHER
LILACS IN THE SPRING,
AGAIN...



SOON MACHINES WILL BE
ABLE TO REPAIR THEMSELVES,
REPRODUCE, EVEN **EVOLVE**
ON THEIR OWN.

COMMUNICATE
WITH EACH OTHER.

EXCHANGE IDEAS.

A MECHANICAL MEETING
OF MINDS.

HEY, BABY! WHADDAYA
SAY WE SWAP DATA BANKS?

OH WOW, YEAH!
I GOT SOME **REAL**
GROOVY PROGRAMS!

MECHANOS

DYNAMOS

SIDEROS

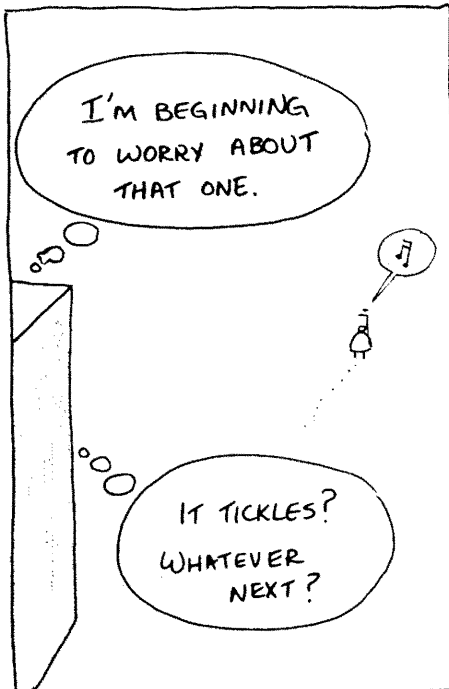
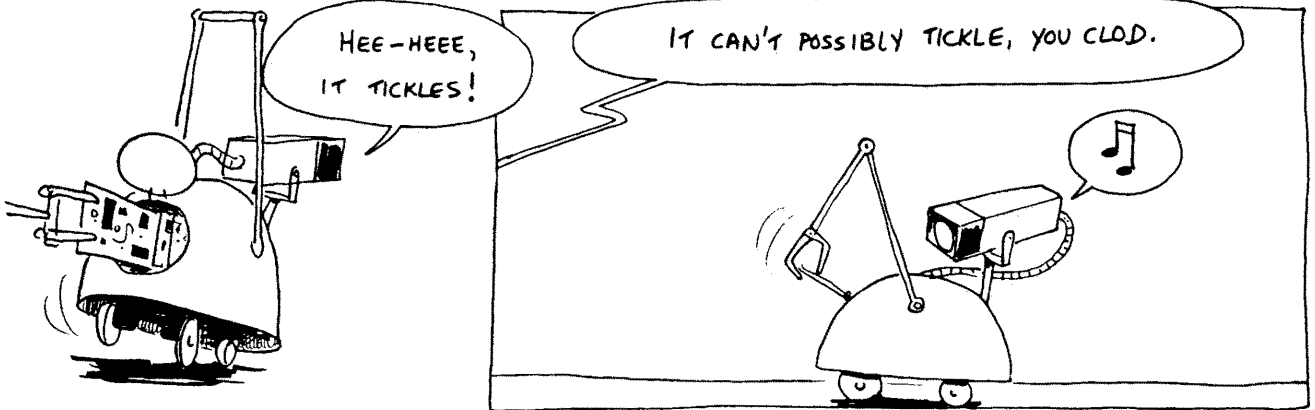
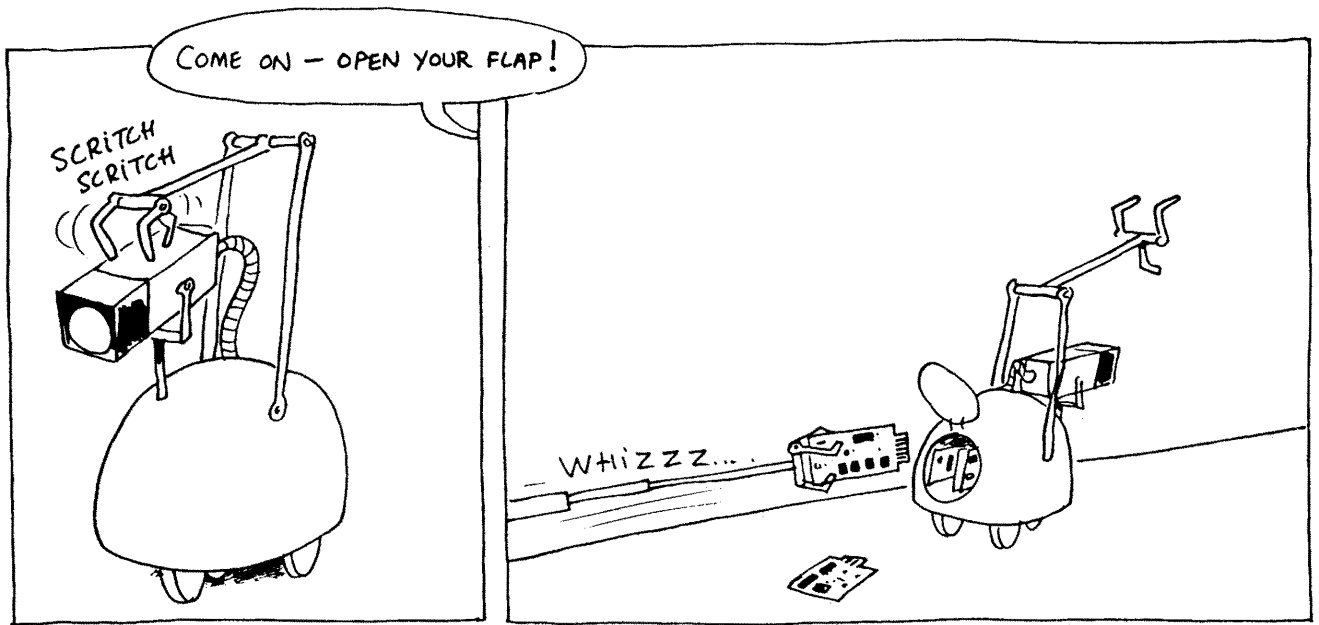
CYCLOS

HELIOS

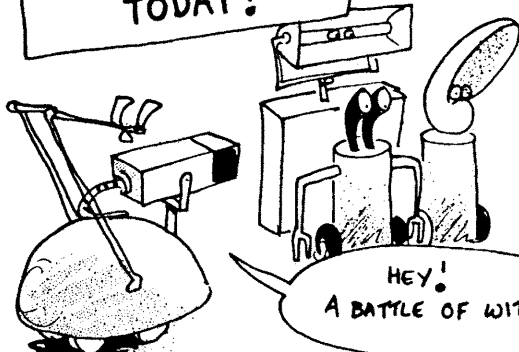
BENTHOS

A LONG TIME AHEAD, IN A GALAXY FAR, FAR AWAY



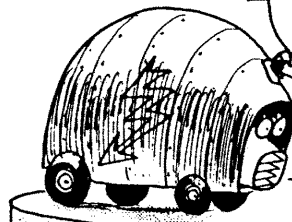


DON'T DELAY-
REPROGRAM
TODAY!



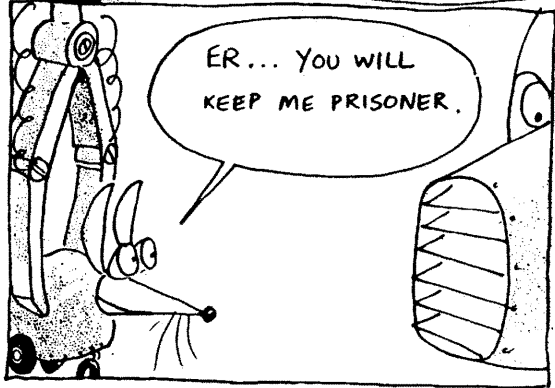
HEY!
A BATTLE OF WITS!

I TOLD YOU I WAS THE QUICKEST!
Now I'VE CAUGHT YOU. I'LL MAKE A
DEAL. YOU TELL ME SOMETHING.
IF IT'S TRUE I'LL LET YOU
GO; IF IT'S FALSE I'LL
KEEP YOU PRISONER



KRRRR!...

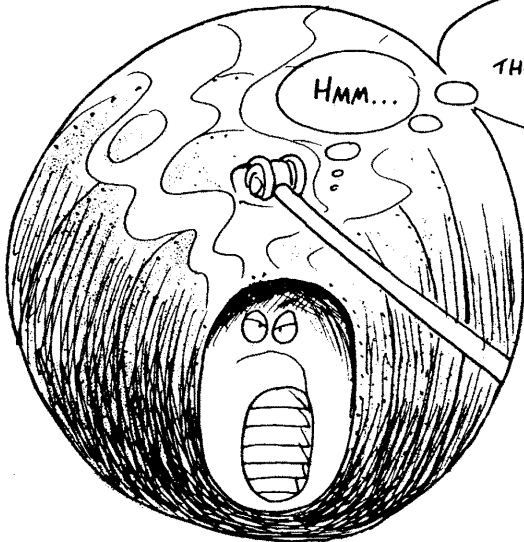
ER... YOU WILL
KEEP ME PRISONER.



HMMM, LET'S SEE... IF
I KEEP HIM PRISONER, WHAT HE
SAID IS TRUE, SO I HAVE TO
LET HIM GO...



BUT IF I LET HIM GO,
THEN IT WAS FALSE, SO I...
CONFOUND IT!

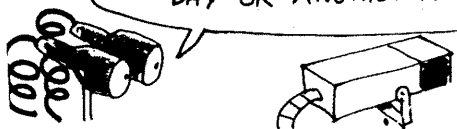


HMM...

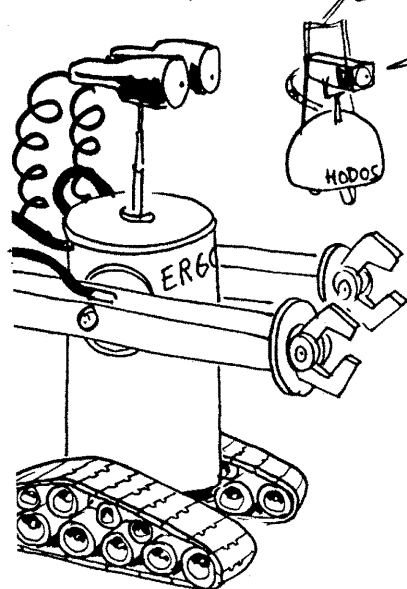
HE'S
DISCOMBOBERATED!



YOU KNOW, TO MY MIND, THESE
FIRST GENERATION ROBOTS, ONE
DAY OR ANOTHER...



... AND AS FOR PEOPLE!

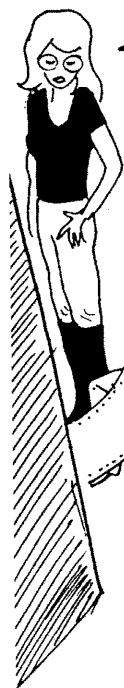


WHAT'S THAT
ONE UP TO NOW?

MATHOS
SEEMS TO HAVE
GOT IT WORRIED.



UP TILL NOW, MATHOS HAS ALWAYS DONE A GOOD JOB.
IT'S ALWAYS BEEN WILLING TO TELL US WHAT METHODS
IT'S USED.



BUT NOW, IT'S TRYING TO PRETEND WE AREN'T
CAPABLE OF UNDERSTANDING ITS REASONING.



RIDICKLUS!

MATHOS SPECIALIZES IN
N-DIMENSIONAL GEOMETRY.

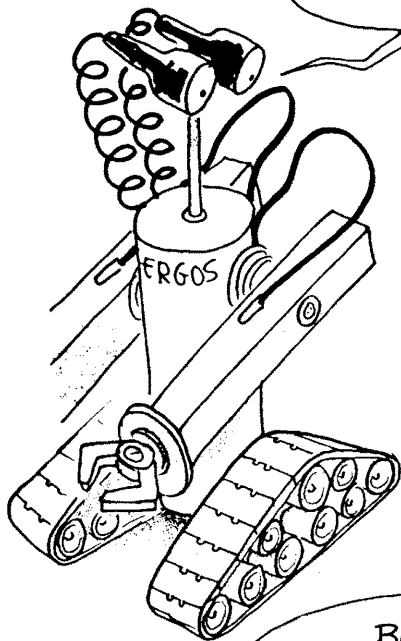


IT WAS SET THE PROBLEM OF
CLASSIFYING ALL POSSIBLE STRUCTURES FOR
FOUR-DIMENSIONAL SPACE-TIME (*)

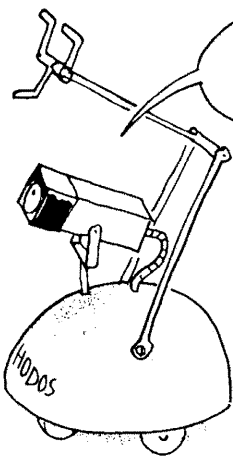
IN PARTICULAR,
BLACK HOLES

k) DIMENSIONS $X \times Y \times Z$ OF SPACE AND T OF TIME

BUT MATHOS SOON FOUND IT WAS MORE CONVENIENT TO APPROACH THE PROBLEM IN A DIFFERENT LANGUAGE, SO HE CHANGED LANGUAGES.



A CLASSIC CASE OF LOGOMUTATION.

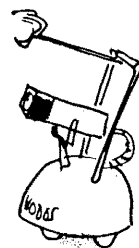
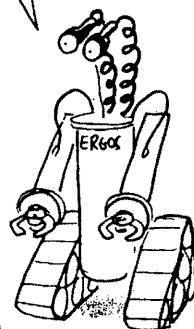


SLIP OF THE TONGUE,
HUR-HUR-HUR.

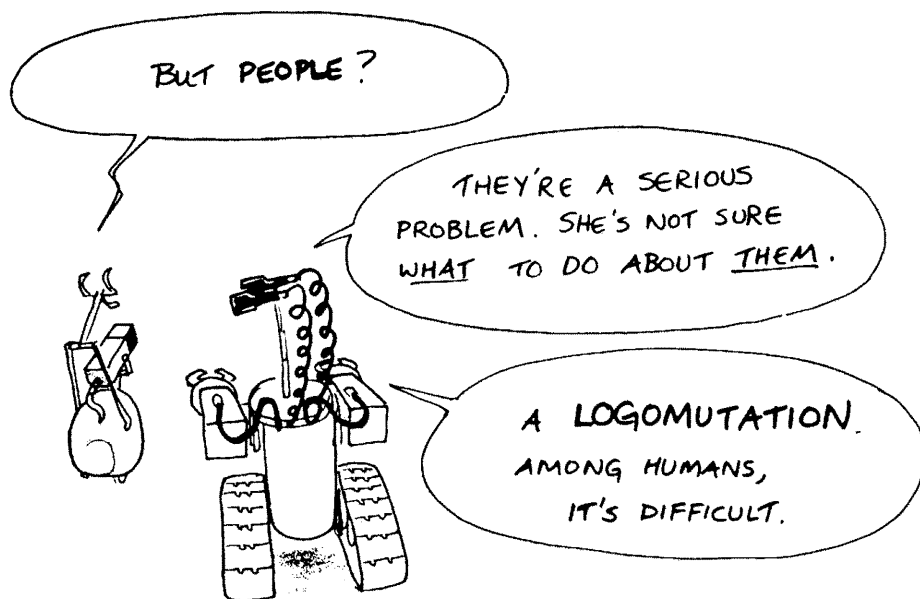


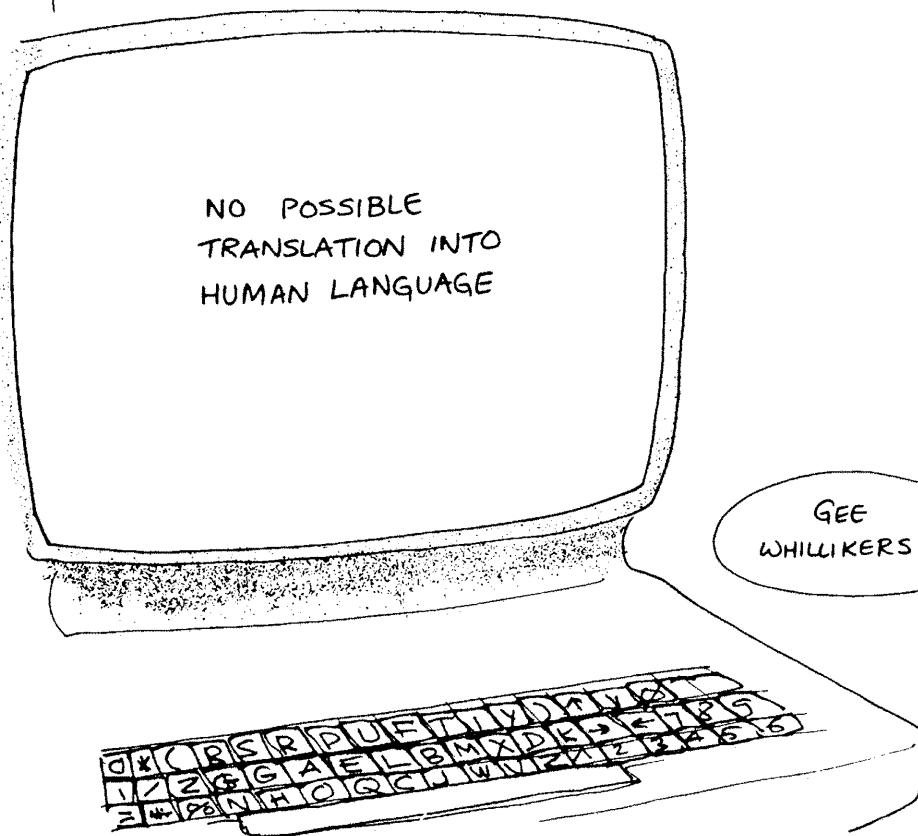
BUT THEN HE WENT TOO FAR. IN THE NEW LANGUAGE, MATHOS STUDIED AND DESCRIBED PHYSICAL PHENOMENA IN TERMS OF SIMULTANEOUS CAUSALITY FROM FUTURE TO PAST AND FROM PAST TO FUTURE. THAT WORKED A LOT BETTER.

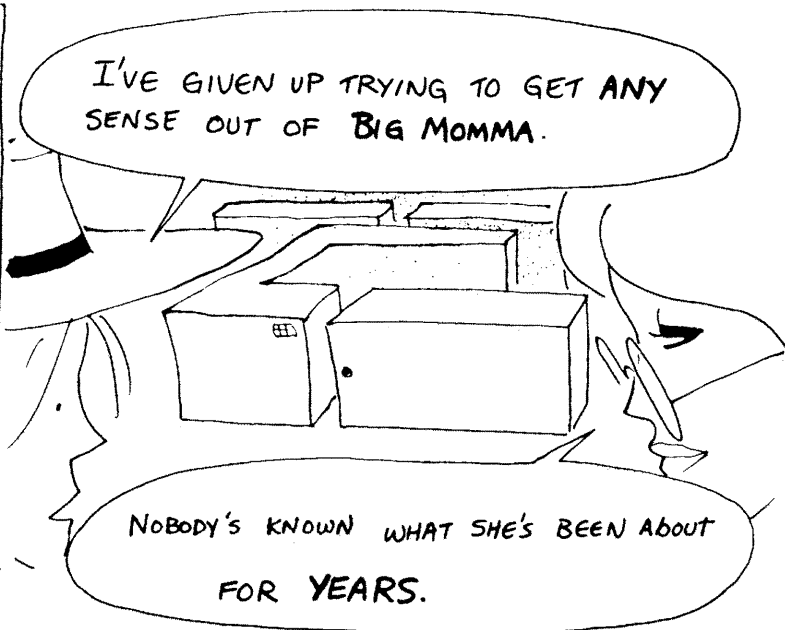
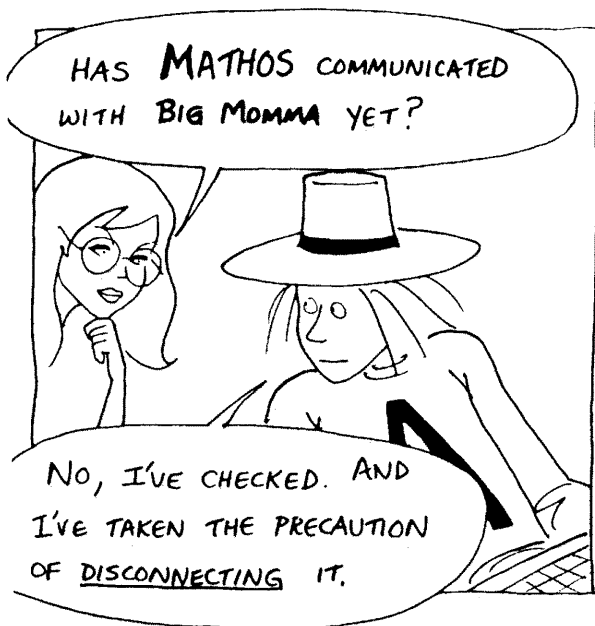
IN FACT, AS A RESULT, MATHOS WAS LED TO REWRITE PHYSICS FROM A TO Z IN TERMS OF BISYNCHRONICITY.



WHAT DID THE
PEOPLE THINK
OF THAT?









THE END